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Logue et al.

(10) **Patent No.: US 9,432,464 B2**
(45) **Date of Patent: Aug. 30, 2016**

(54) **TIME VARIANT DATA PROFILE FOR A FABRIC NETWORK**

(71) Applicant: **Google Inc.**, Mountain View, CA (US)

(72) Inventors: **Jay D. Logue**, San Jose, CA (US); **Grant M. Erickson**, Sunnyvale, CA (US); **Sunny Vardhan Gujjaru**, Mountain View, CA (US); **Michael Dixon**, Sunnyvale, CA (US); **Jiakang Lu**, Mountain View, CA (US)

(73) Assignee: **GOOGLE INC.**, Mountain View, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **14/665,913**

(22) Filed: **Mar. 23, 2015**

(65) **Prior Publication Data**

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Related U.S. Application Data

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(51) **Int. Cl.**

G06F 15/16	(2006.01)
H04L 29/08	(2006.01)
G08B 29/02	(2006.01)
F24F 11/00	(2006.01)
G05B 15/02	(2006.01)
G06F 17/30	(2006.01)

(Continued)

(52) **U.S. Cl.**

CPC ***H04L 67/141*** (2013.01); ***F24F 11/006*** (2013.01); ***G05B 15/02*** (2013.01); ***G06F 17/30722*** (2013.01); ***G08B 29/02*** (2013.01); ***H04L 12/281*** (2013.01); ***H04L 29/06*** (2013.01); ***H04L 41/0816*** (2013.01); ***H04L 43/0805*** (2013.01); ***H04L 45/02*** (2013.01); ***H04L 45/74*** (2013.01); ***H04L 63/08*** (2013.01); ***H04L 67/10*** (2013.01); ***H04L 67/12*** (2013.01); ***H04L 67/143*** (2013.01); ***H04L 67/303*** (2013.01)

(58) **Field of Classification Search**

USPC 709/203, 217–219, 223–229, 250

See application file for complete search history.

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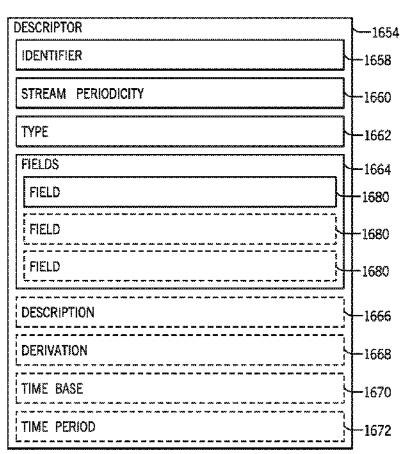
Primary Examiner — Zarni Maung

(57) **ABSTRACT**

Systems and methods for exchanging a data stream of information that varies over time using a message format. The message format includes a version field that indicates a version of a structure of the message format. The message format also includes one or more resources fields that each identifies a resource to be imported into the data stream exchanging the data stream. Moreover, the message format includes one or more records that represent time-variant data samples being exchanged in the message. Furthermore, the message format includes one or more descriptor fields, wherein each descriptor field corresponds to at least one respective record of the one or more records and contains metadata describing data contained within the at least one record.

20 Claims, 25 Drawing Sheets



(51) **Int. Cl.**

H04L 29/06	(2006.01)
H04L 12/24	(2006.01)
H04L 12/28	(2006.01)
H04L 12/26	(2006.01)
H04L 12/751	(2013.01)
H04L 12/741	(2013.01)
G06F 12/00	(2006.01)

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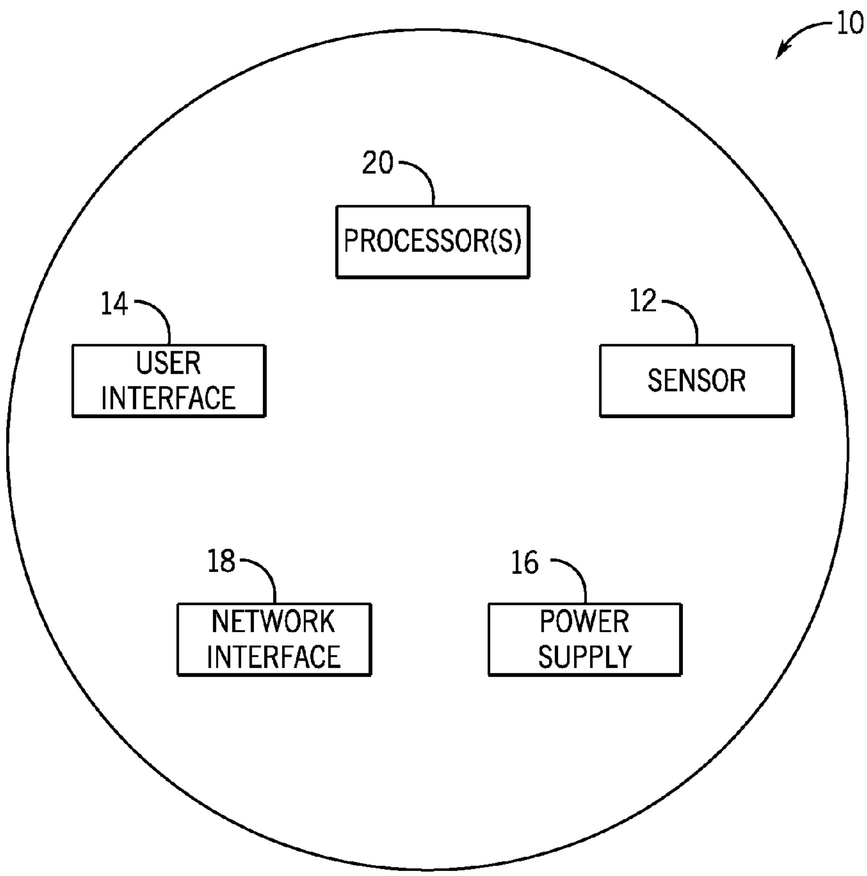

10
20
PROCESSOR(S)
14
USER INTERFACE
12
SENSOR
18
NETWORK INTERFACE
16
POWER SUPPLY

FIG. 1

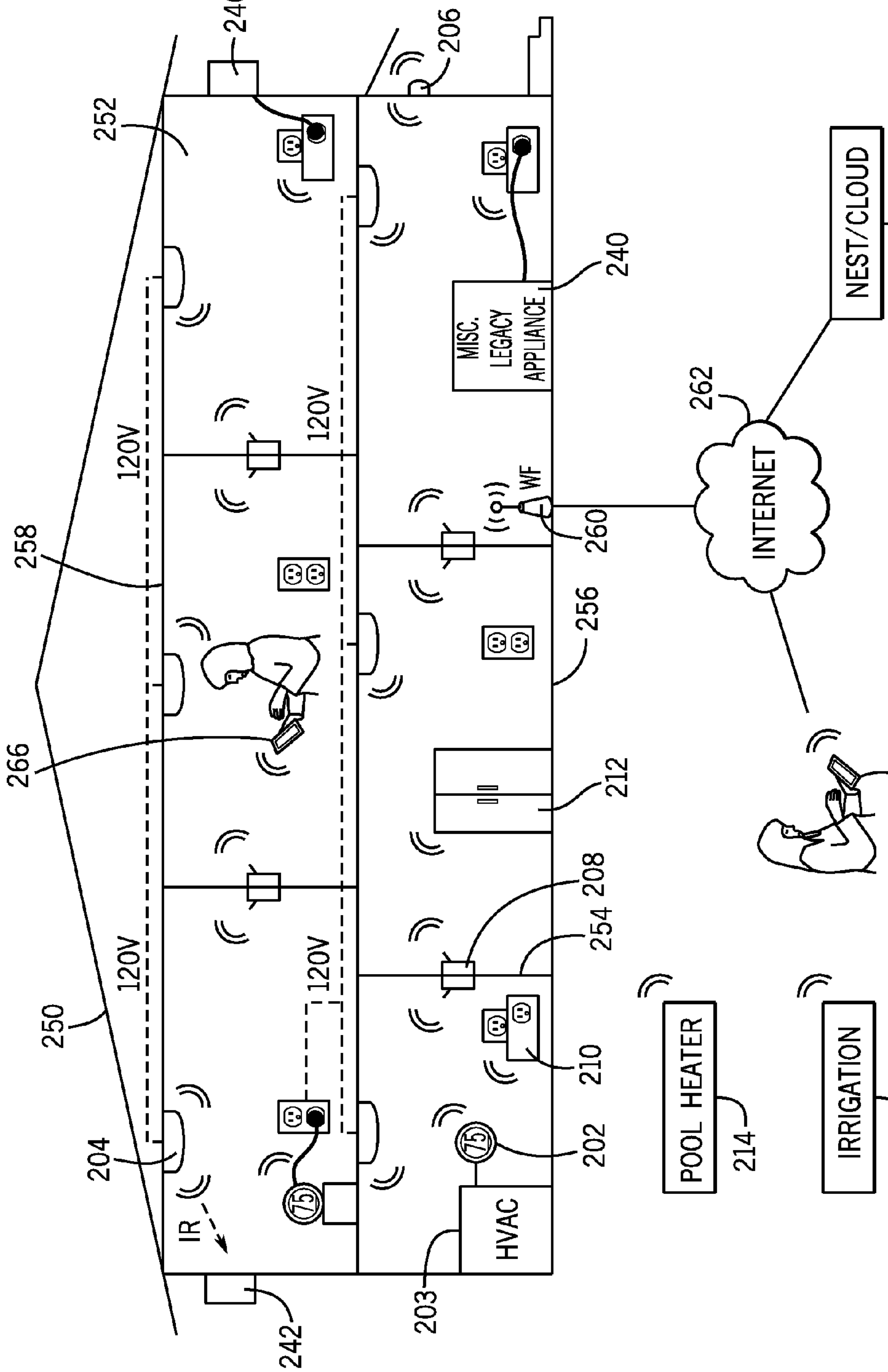

240
206
252
240
MISC. LEGACY APPLIANCE
NEST/CLOUD
264
262
INTERNET
120V
120V
120V
120V
WF
260
258
256
266
212
266
208
254
250
POOL HEATER
214
IRRIGATION
216
210
204
202
75
75
IR
HVAC
203
242

FIG. 2

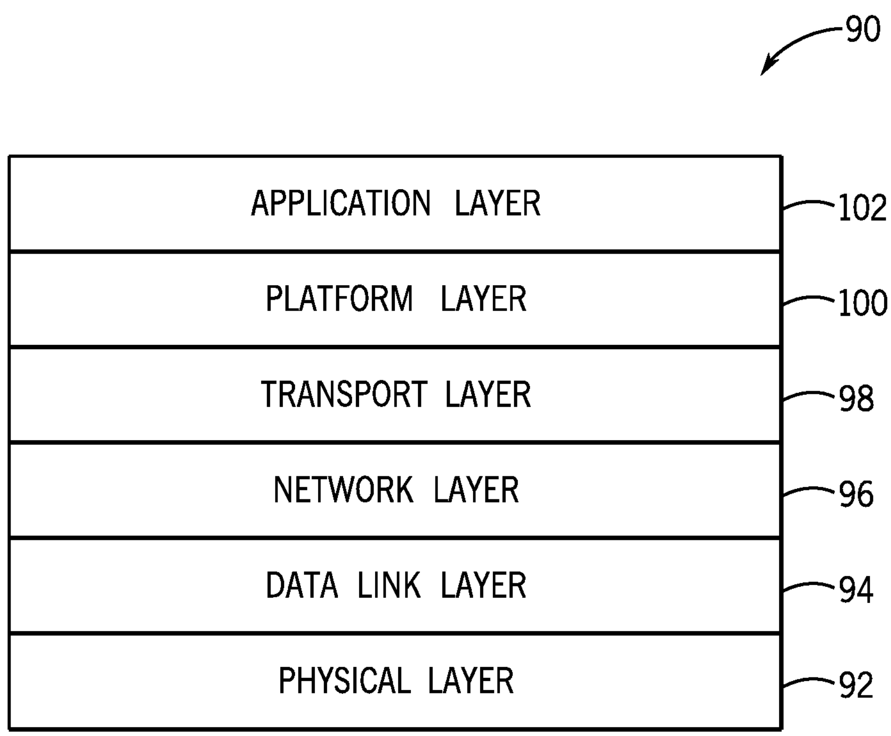

90
APPLICATION LAYER
102
PLATFORM LAYER
100
TRANSPORT LAYER
98
NETWORK LAYER
96
DATA LINK LAYER
94
PHYSICAL LAYER
92

FIG. 3

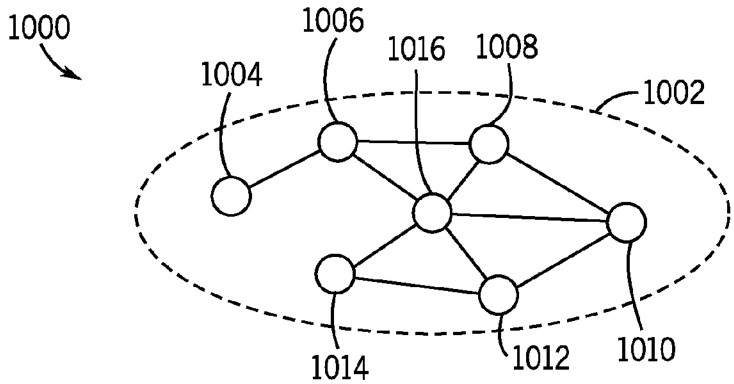


FIG. 4

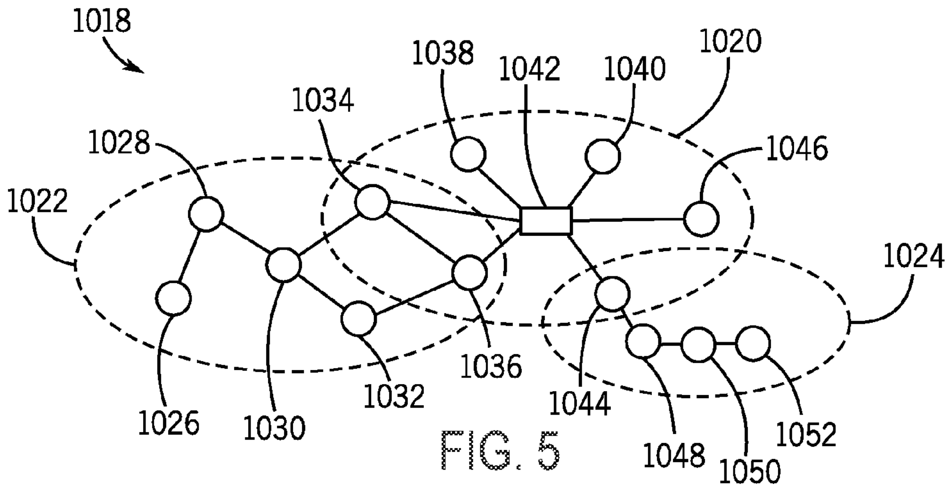


FIG. 5

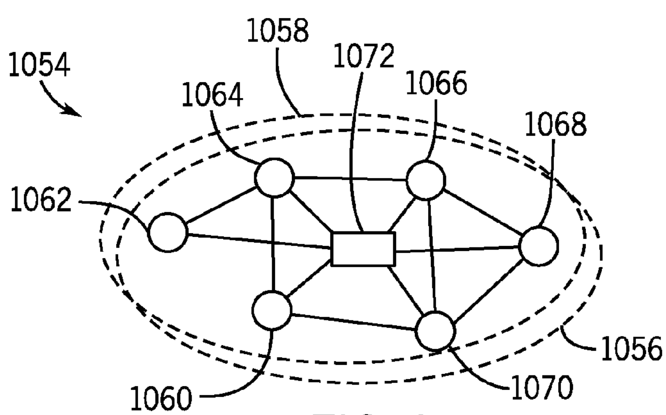


FIG. 6

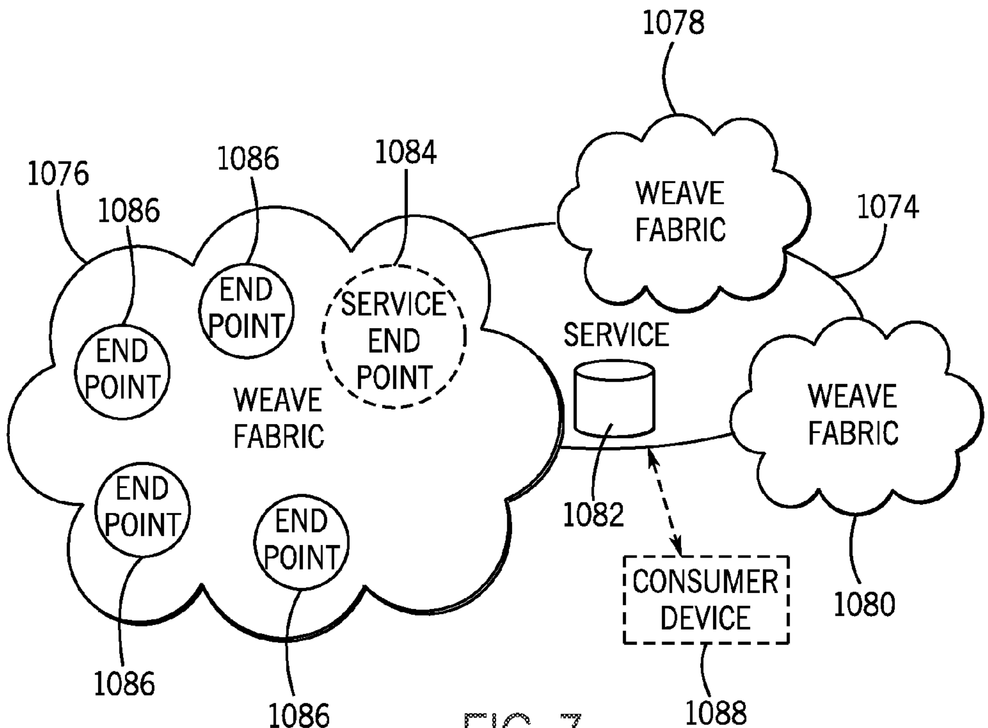

1078
1076
1086
1084
1074
WEAVE
FABRIC
END
POINT
SERVICE
END
POINT
SERVICE
WEAVE
FABRIC
WEAVE
FABRIC
1082
1080
CONSUMER
DEVICE
1086
1086
1088

FIG. 7

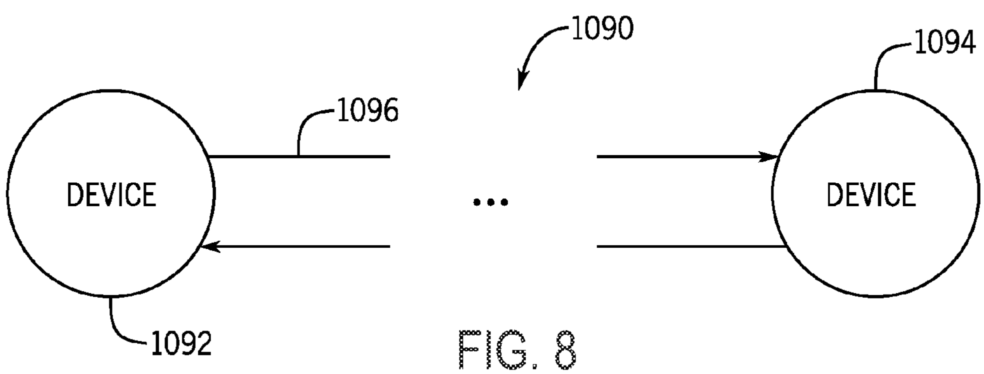

1090
1094
1096
DEVICE
...
DEVICE
1092

FIG. 8

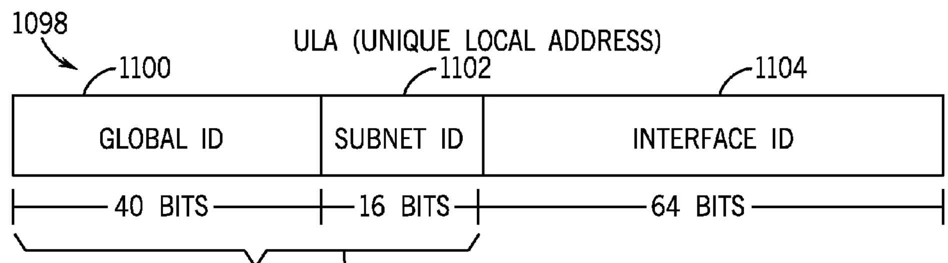

1098
ULA (UNIQUE LOCAL ADDRESS)
1100
1102
1104
GLOBAL ID
SUBNET ID
INTERFACE ID
40 BITS
16 BITS
64 BITS
FABRIC ID
1103

FIG. 9

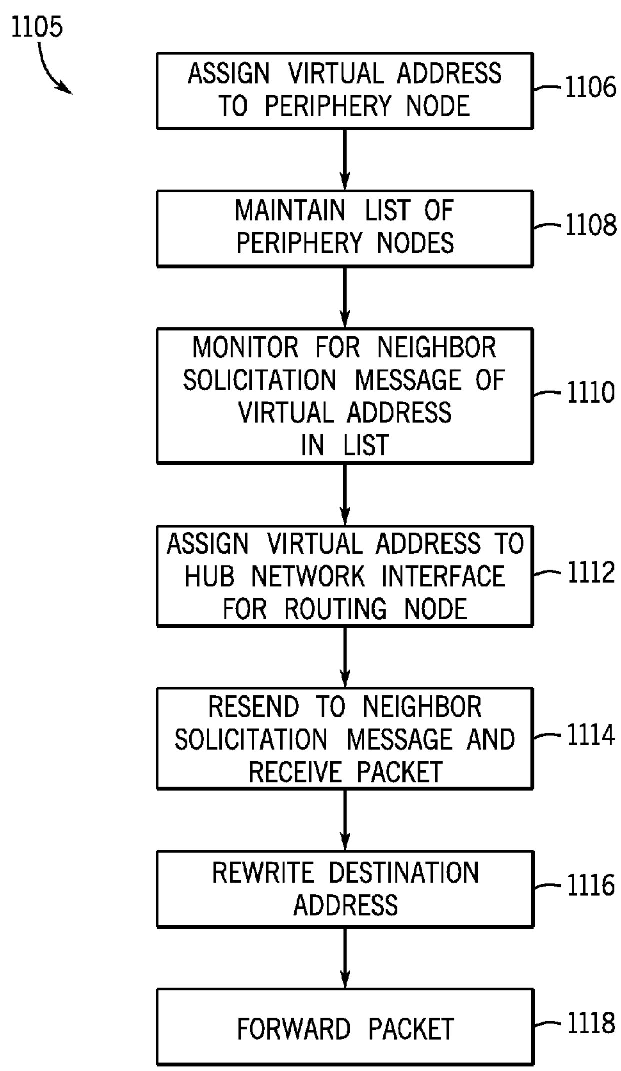

1105
ASSIGN VIRTUAL ADDRESS TO PERIPHERY NODE
1106
MAINTAIN LIST OF PERIPHERY NODES
1108
MONITOR FOR NEIGHBOR SOLICITATION MESSAGE OF VIRTUAL ADDRESS IN LIST
1110
ASSIGN VIRTUAL ADDRESS TO HUB NETWORK INTERFACE FOR ROUTING NODE
1112
RESEND TO NEIGHBOR SOLICITATION MESSAGE AND RECEIVE PACKET
1114
REWRITE DESTINATION ADDRESS
1116
FORWARD PACKET
1118

FIG. 10

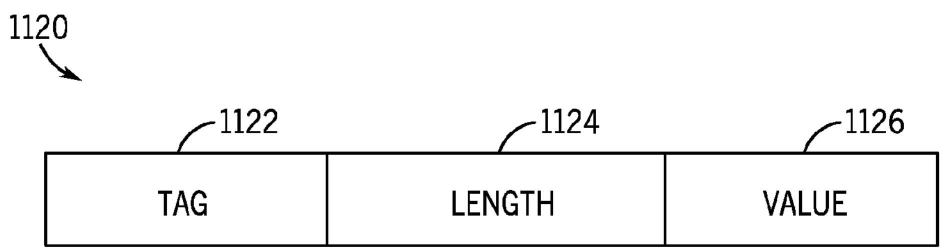


FIG. 11

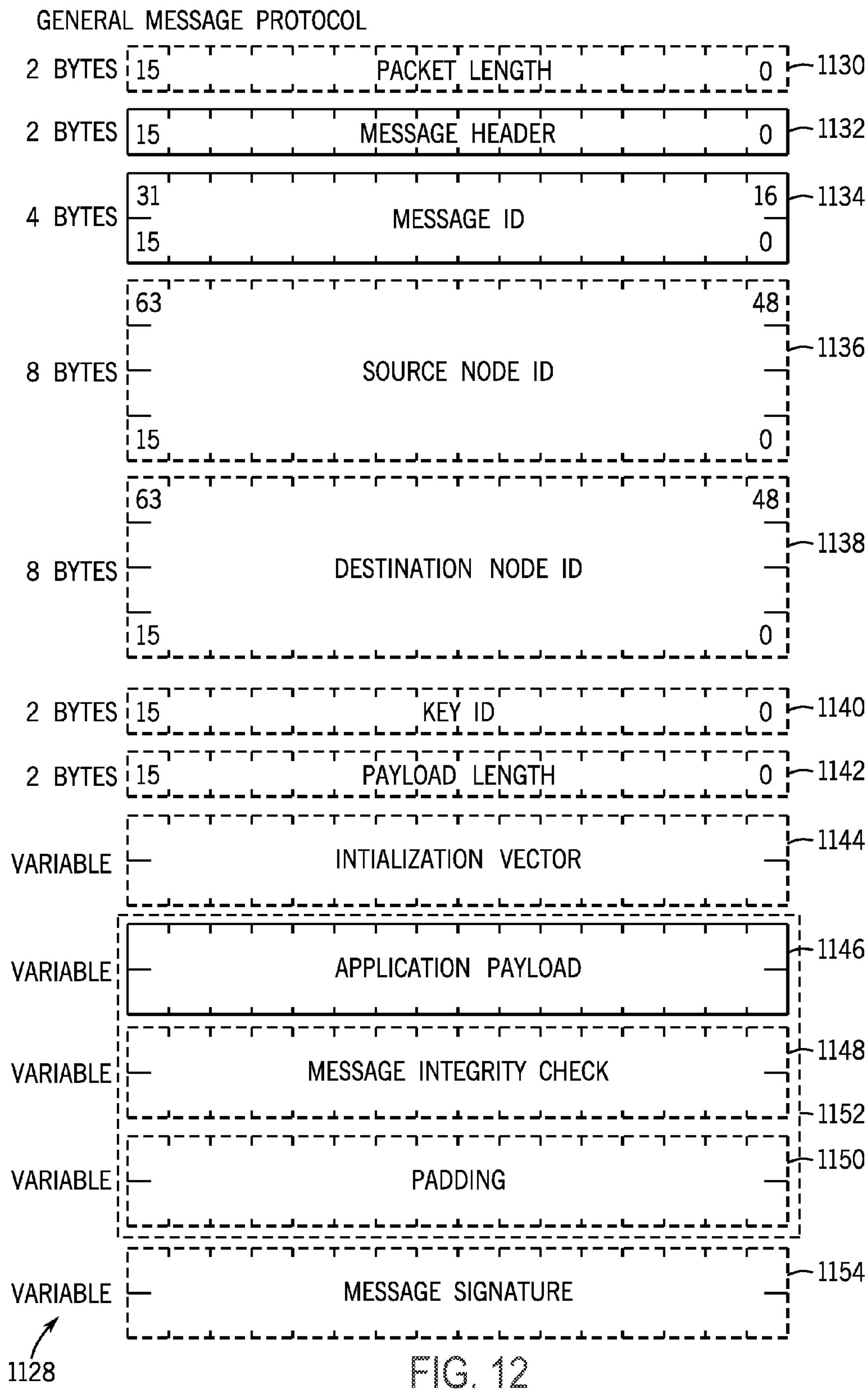

GENERAL MESSAGE PROTOCOL
2 BYTES
15
PACKET LENGTH
0
1130
2 BYTES
15
MESSAGE HEADER
0
1132
4 BYTES
31
16
MESSAGE ID
15
0
1134
63
48
8 BYTES
SOURCE NODE ID
15
0
1136
63
48
8 BYTES
DESTINATION NODE ID
15
0
1138
2 BYTES
15
KEY ID
0
1140
2 BYTES
15
PAYLOAD LENGTH
0
1142
VARIABLE
INTIALIZATION VECTOR
1144
VARIABLE
APPLICATION PAYLOAD
1146
VARIABLE
MESSAGE INTEGRITY CHECK
1148
1152
VARIABLE
PADDING
1150
VARIABLE
MESSAGE SIGNATURE
1154
1128

FIG. 12

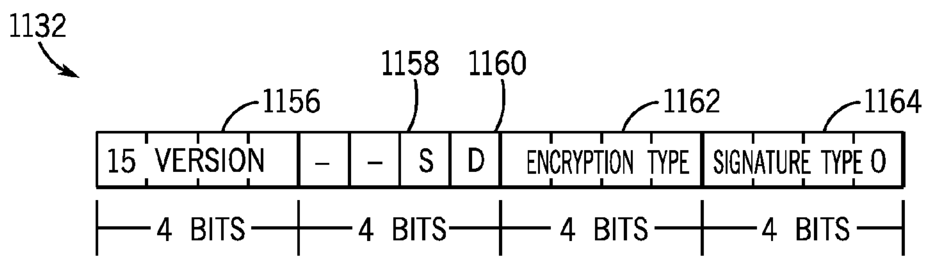

1132
1156
1158
1160
1162
1164
15 VERSION
–
–
S
D
ENCRYPTION TYPE
SIGNATURE TYPE 0
4 BITS
4 BITS
4 BITS
4 BITS

FIG. 13

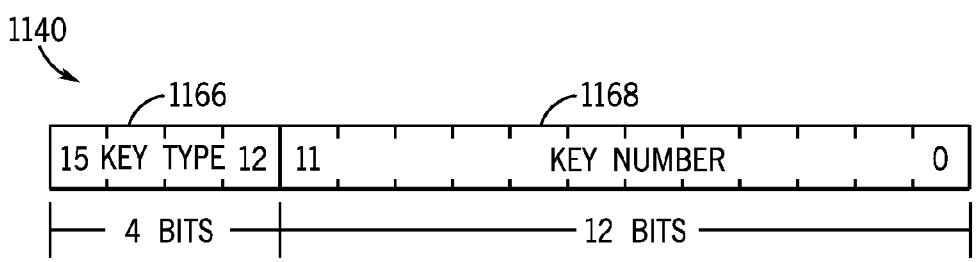

1140
1166
1168
15 KEY TYPE 12
11
KEY NUMBER
0
4 BITS
12 BITS

FIG. 14

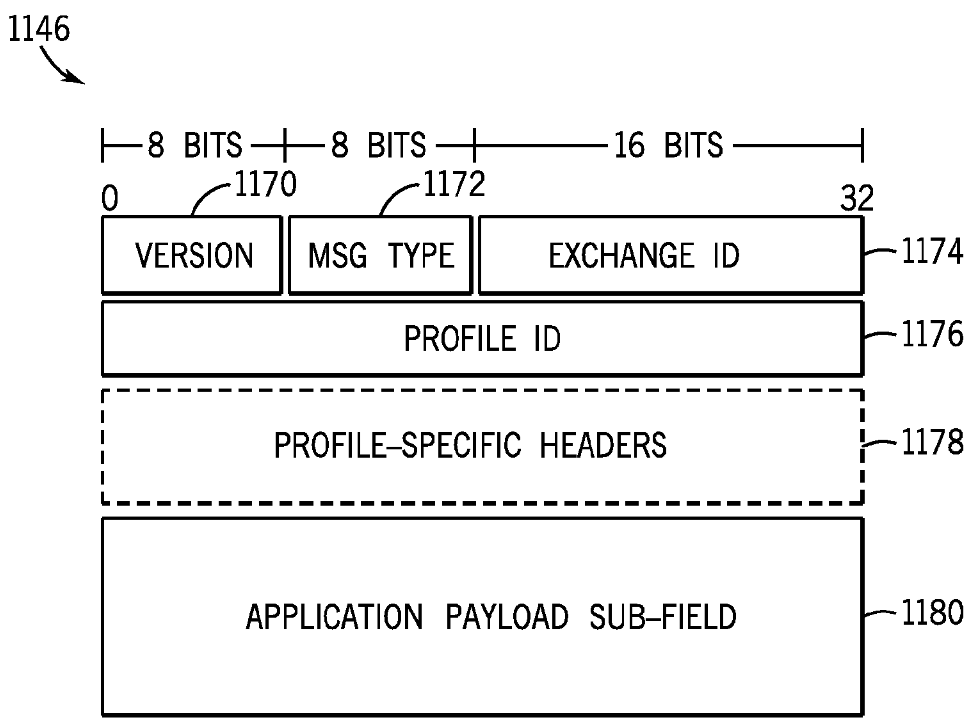

1146
8 BITS
8 BITS
16 BITS
0
1170
1172
32
VERSION
MSG TYPE
EXCHANGE ID
1174
PROFILE ID
1176
PROFILE–SPECIFIC HEADERS
1178
APPLICATION PAYLOAD SUB–FIELD
1180

FIG. 15

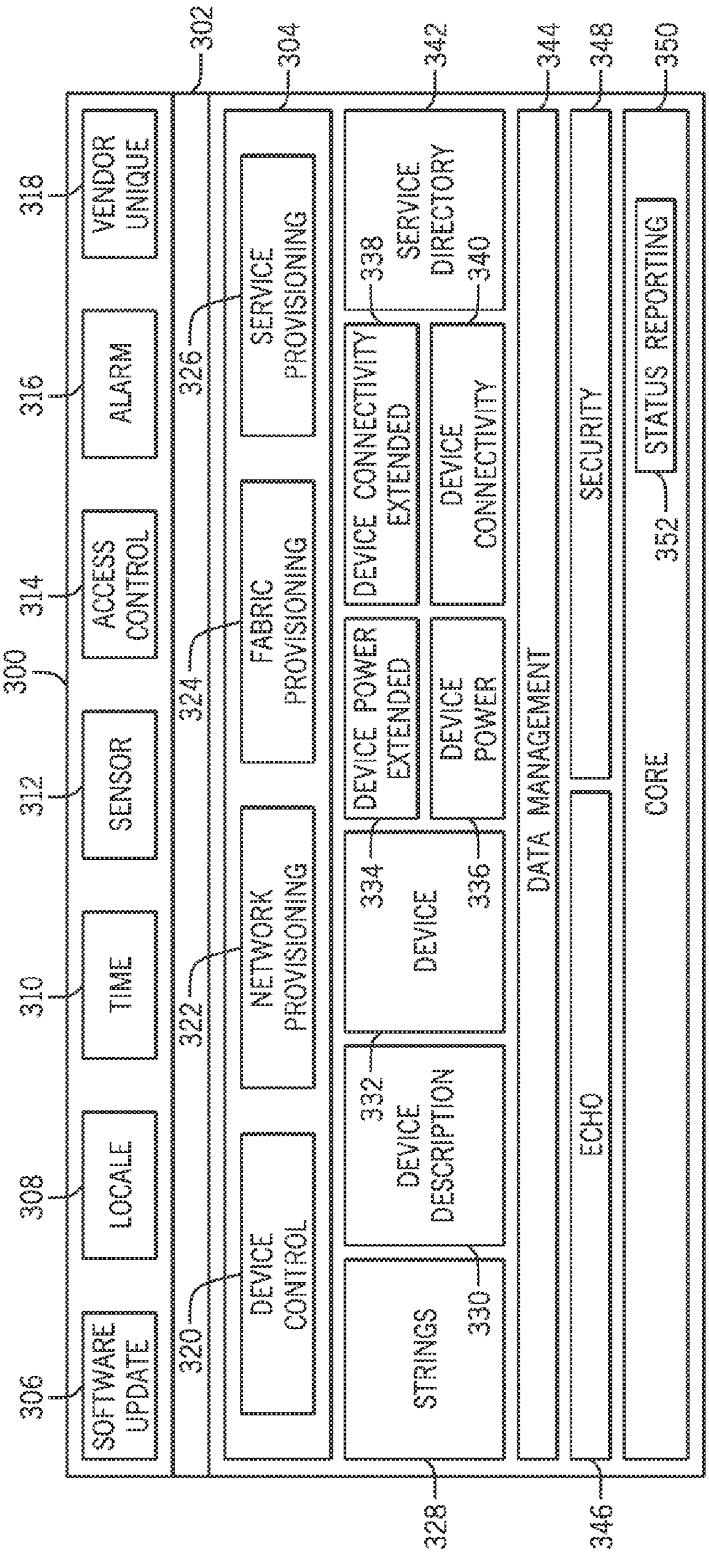

300
302
304
306
SOFTWARE UPDATE
308
LOCALE
310
TIME
312
SENSOR
314
ACCESS CONTROL
316
ALARM
318
VENDOR UNIQUE
320
DEVICE CONTROL
322
NETWORK PROVISIONING
324
FABRIC PROVISIONING
326
SERVICE PROVISIONING
328
STRINGS
330
332
DEVICE DESCRIPTION
334
DEVICE
336
DEVICE POWER EXTENDED
DEVICE POWER
338
DEVICE CONNECTIVITY EXTENDED
340
DEVICE CONNECTIVITY
342
SERVICE DIRECTORY
344
DATA MANAGEMENT
346
ECHO
348
SECURITY
350
CORE
352
STATUS REPORTING

FIG. 16

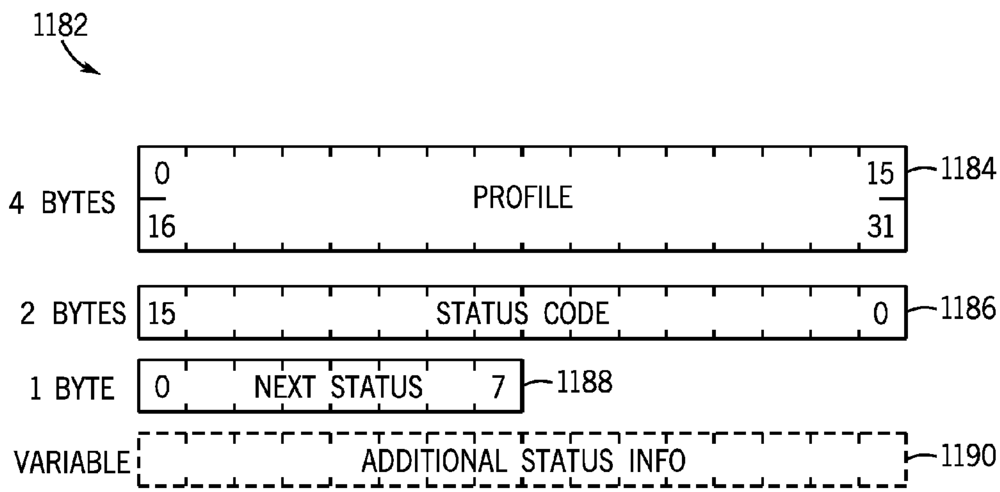

1182
4 BYTES
0
PROFILE
15
16
31
1184
2 BYTES
15
STATUS CODE
0
1186
1 BYTE
0
NEXT STATUS
7
1188
VARIABLE
ADDITIONAL STATUS INFO
1190

FIG. 17

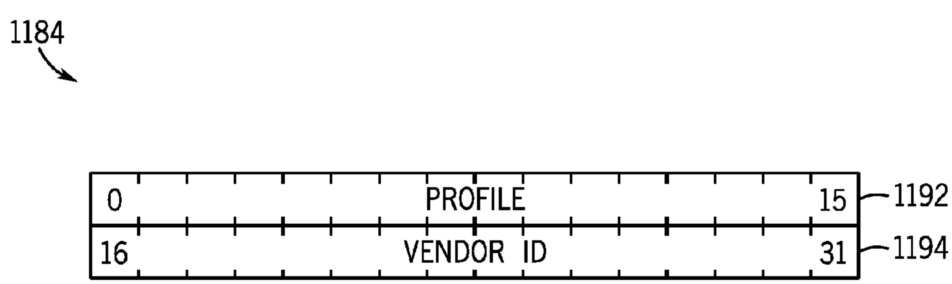

1184
0
PROFILE
15
1192
16
VENDOR ID
31
1194

FIG. 18

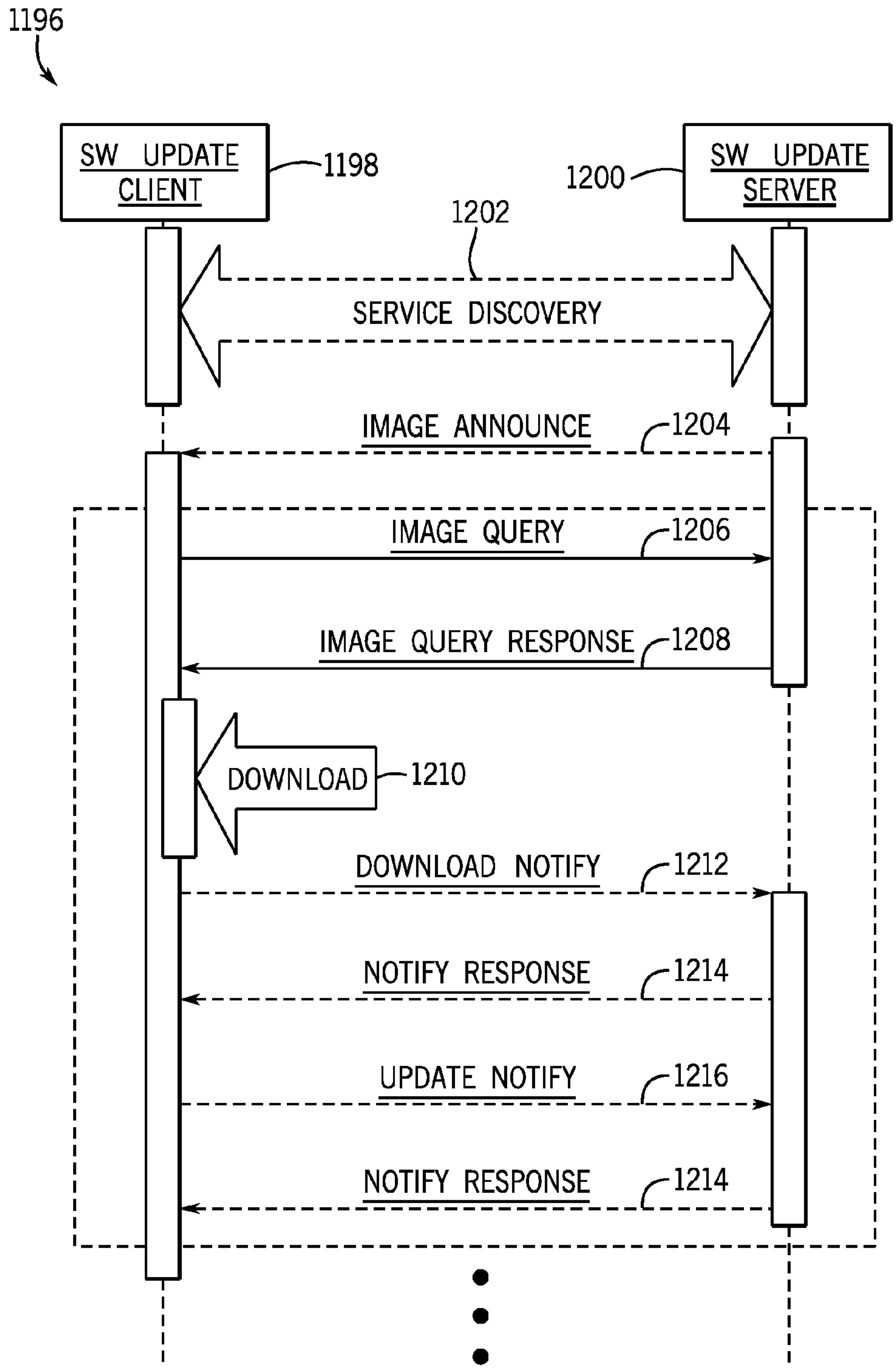

1196
SW UPDATE CLIENT
1198
1200
SW UPDATE SERVER
1202
SERVICE DISCOVERY
IMAGE ANNOUNCE
1204
IMAGE QUERY
1206
IMAGE QUERY RESPONSE
1208
DOWNLOAD
1210
DOWNLOAD NOTIFY
1212
NOTIFY RESPONSE
1214
UPDATE NOTIFY
1216
NOTIFY RESPONSE
1214

FIG. 19

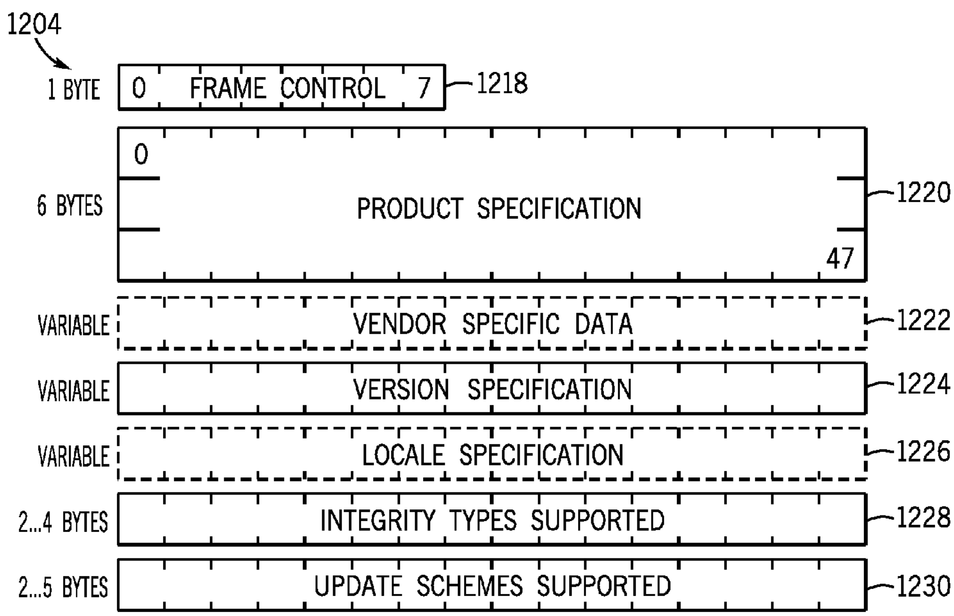


FIG. 20

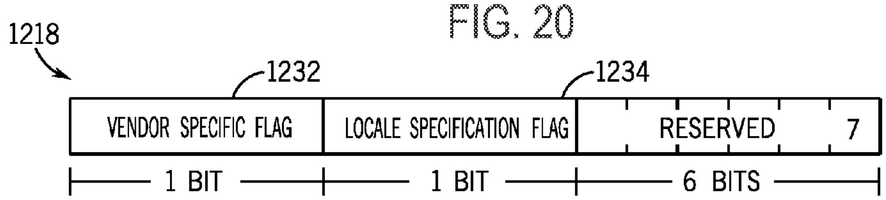


FIG. 21

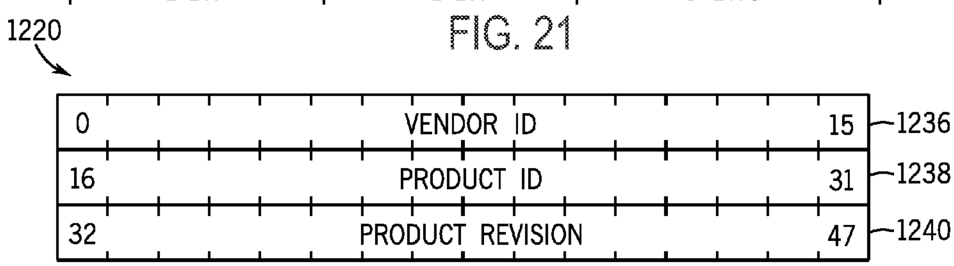


FIG. 22

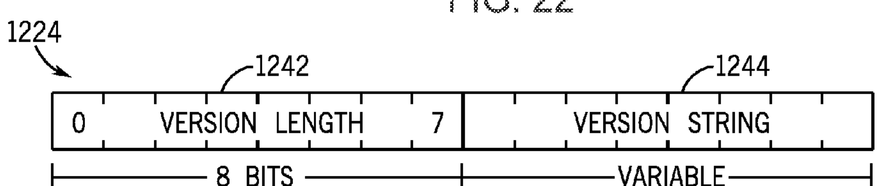


FIG. 23

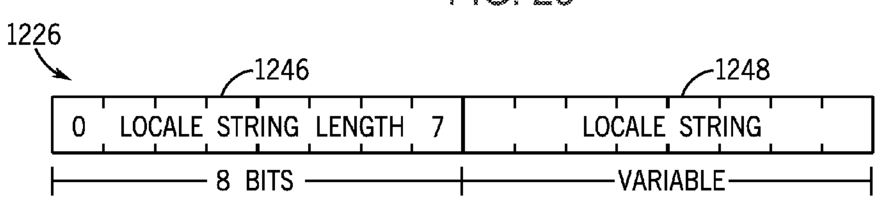


FIG. 24

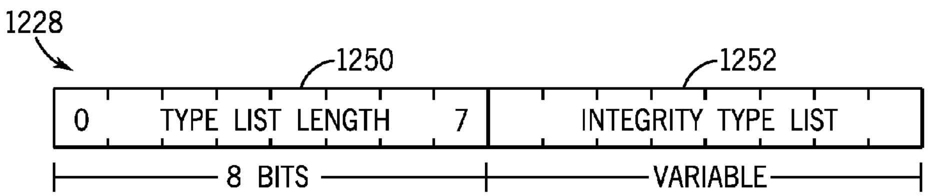


FIG. 25

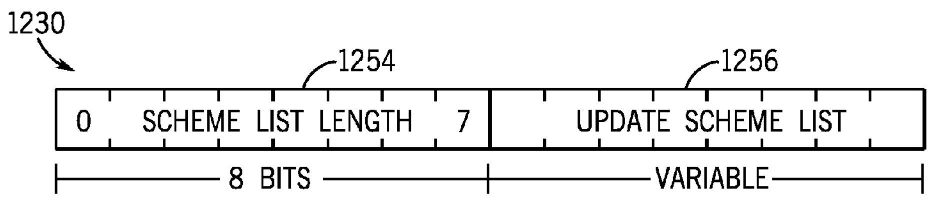


FIG. 26

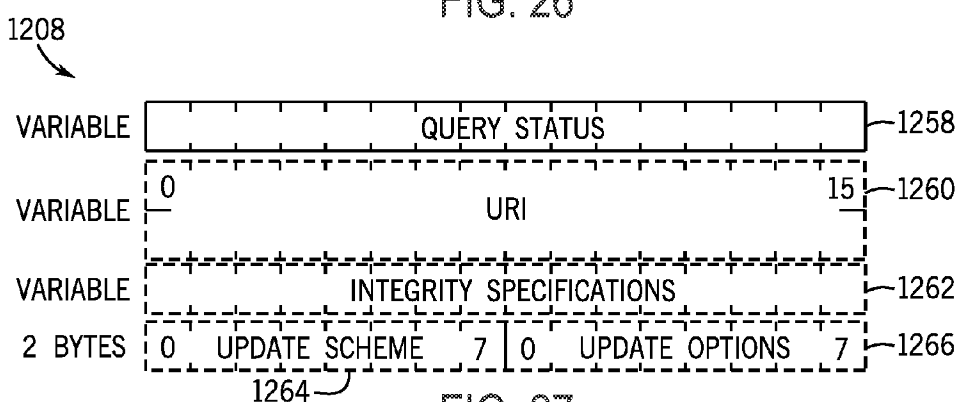


FIG. 27

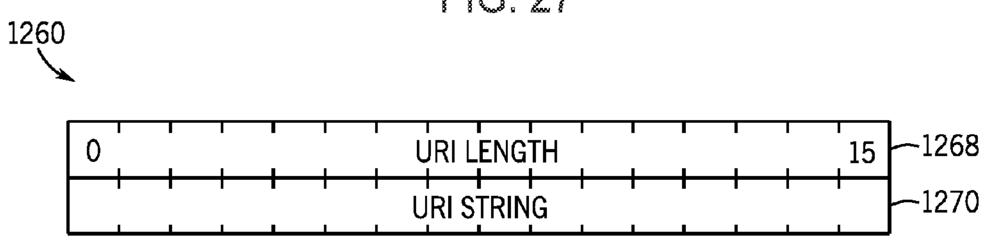


FIG. 28

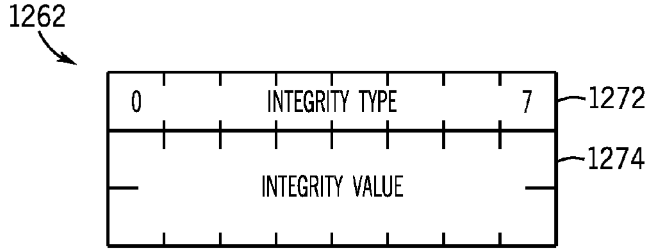


FIG. 29

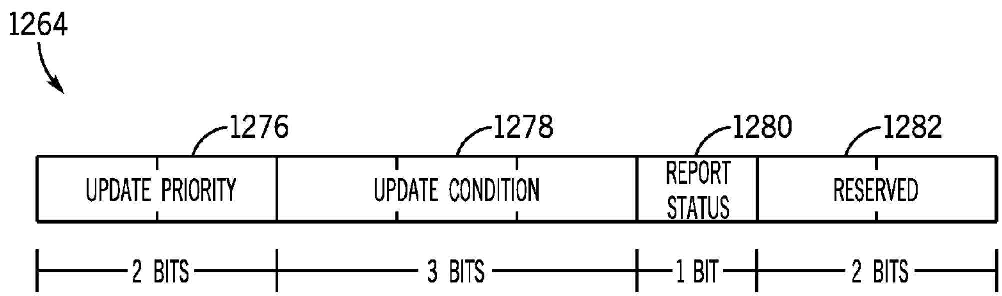

1264
1276
1278
1280
1282
UPDATE PRIORITY
UPDATE CONDITION
REPORT STATUS
RESERVED
2 BITS
3 BITS
1 BIT
2 BITS

FIG. 30

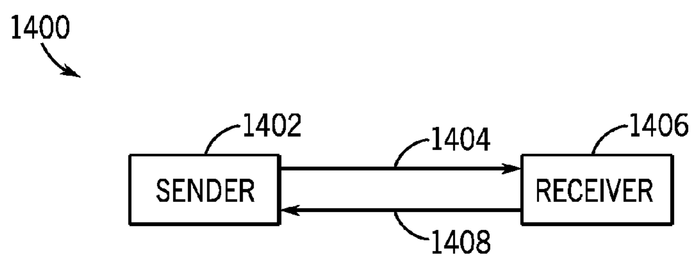
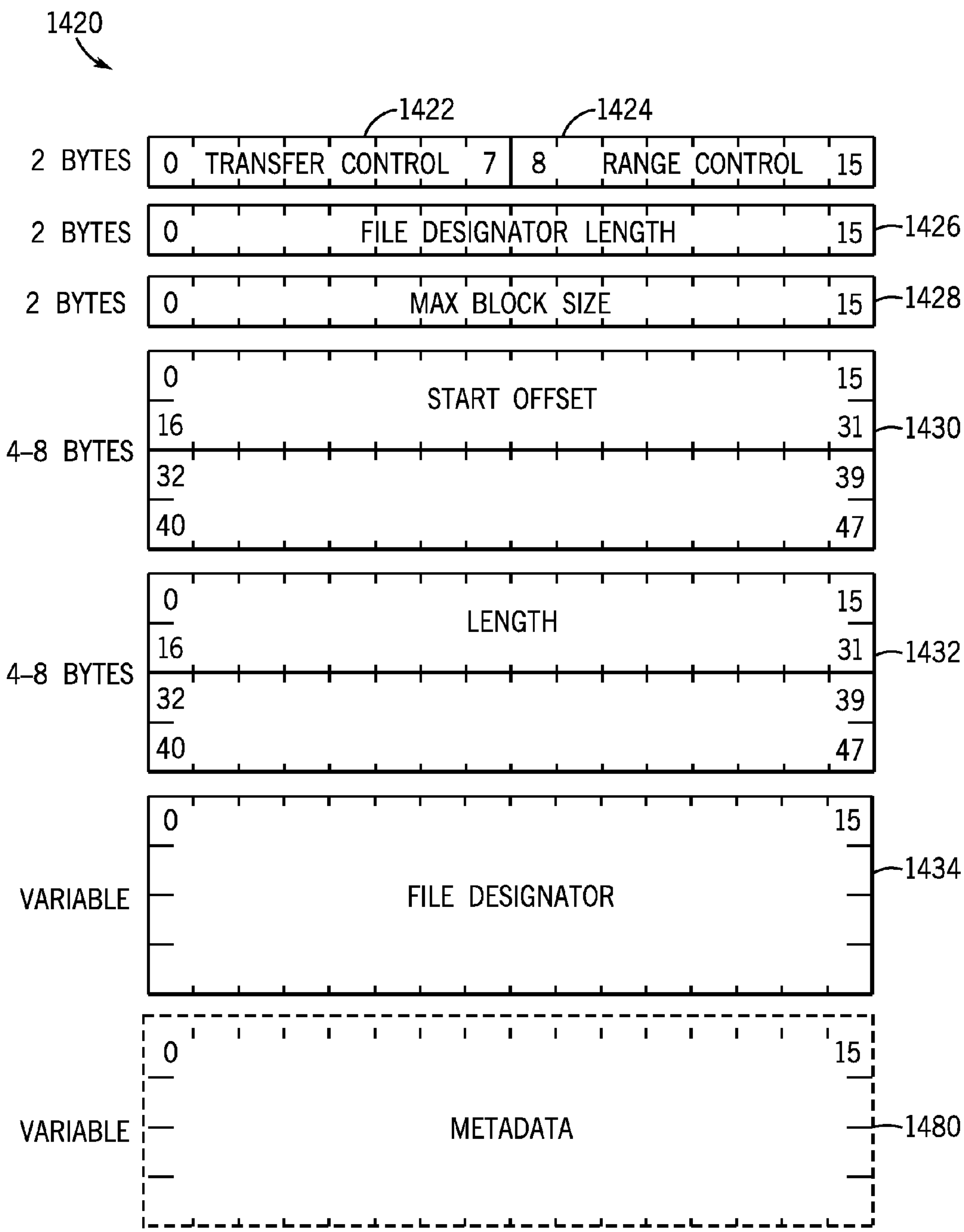

1400
1402
1404
1406
1408
SENDER
RECEIVER

FIG. 31



1420
1422
1424
2 BYTES
0 TRANSFER CONTROL 7
8 RANGE CONTROL 15
2 BYTES
0 FILE DESIGNATOR LENGTH 15
1426
2 BYTES
0 MAX BLOCK SIZE 15
1428
4-8 BYTES
0 START OFFSET 15
16 31
32 39
40 47
1430
4-8 BYTES
0 LENGTH 15
16 31
32 39
40 47
1432
VARIABLE
0 FILE DESIGNATOR 15
1434
VARIABLE
0 METADATA 15
1480

FIG. 32

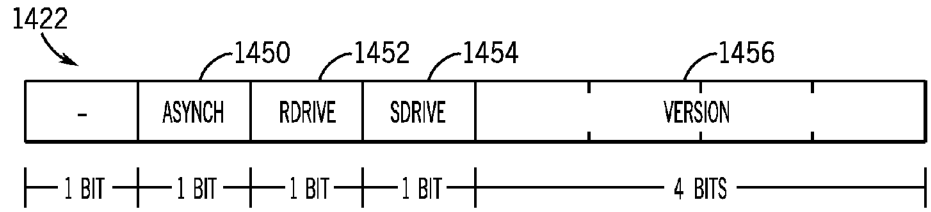


FIG. 33

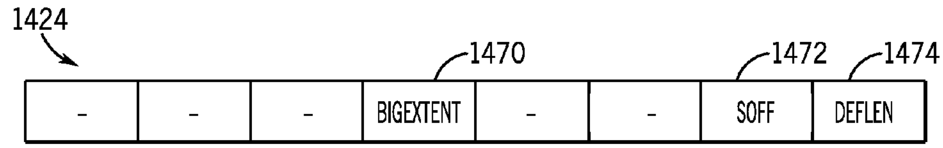


FIG. 34

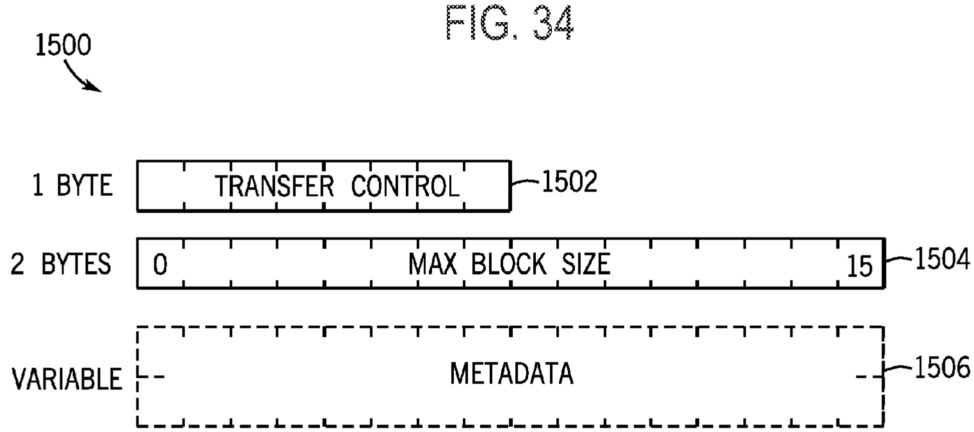


FIG. 35

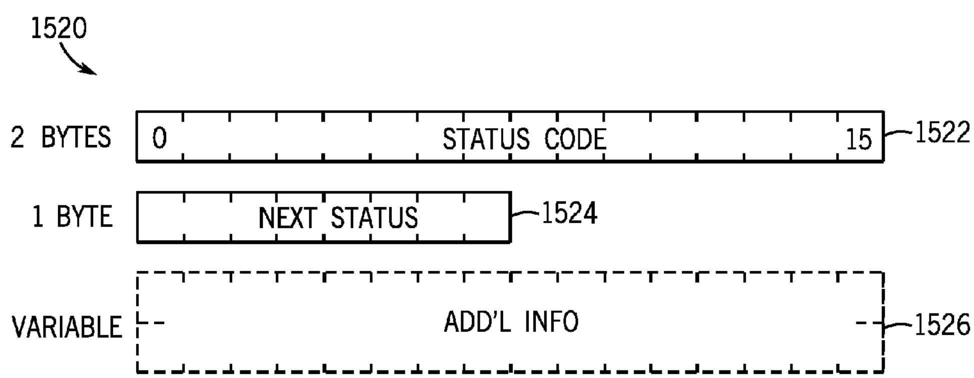


FIG. 36

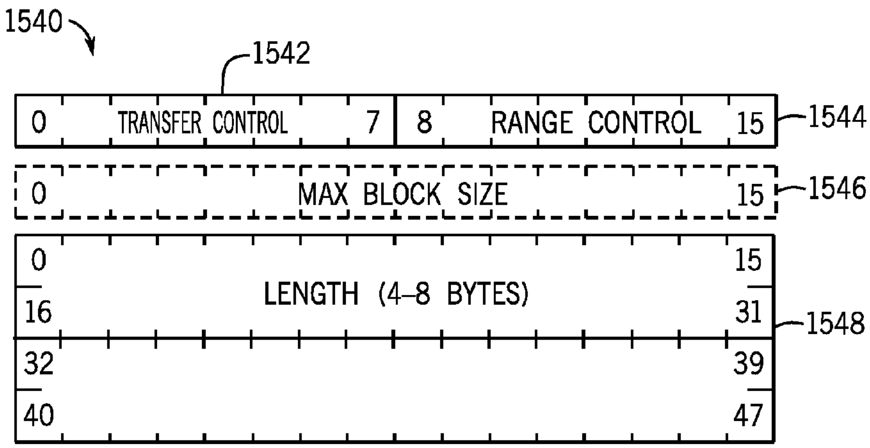

1540
1542
0
TRANSFER CONTROL
7
8
RANGE CONTROL
15
1544
0
MAX BLOCK SIZE
15
1546
0
15
LENGTH (4–8 BYTES)
16
31
1548
32
39
40
47

FIG. 37

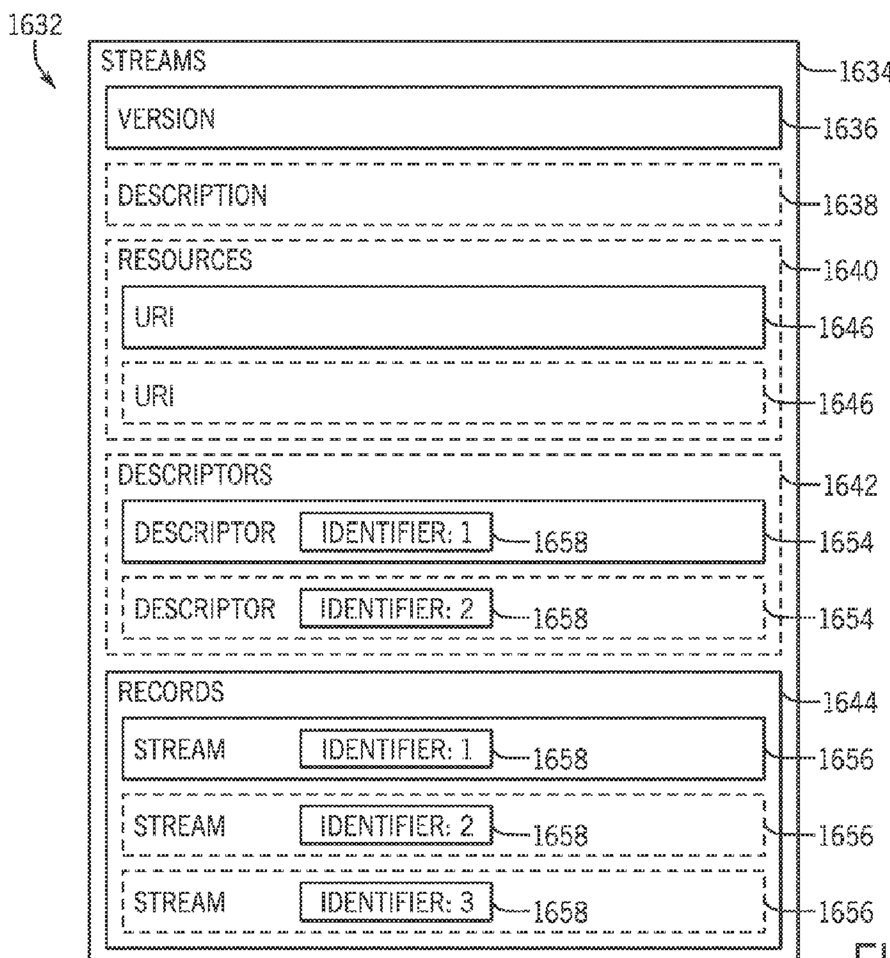

1632
STREAMS
1634
VERSION
1636
DESCRIPTION
1638
RESOURCES
1640
URI
1646
URI
1646
DESCRIPTORS
1642
DESCRIPTOR
IDENTIFIER: 1
1658
1654
DESCRIPTOR
IDENTIFIER: 2
1658
1654
RECORDS
1644
STREAM
IDENTIFIER: 1
1658
1656
STREAM
IDENTIFIER: 2
1658
1656
STREAM
IDENTIFIER: 3
1658
1656

FIG. 38

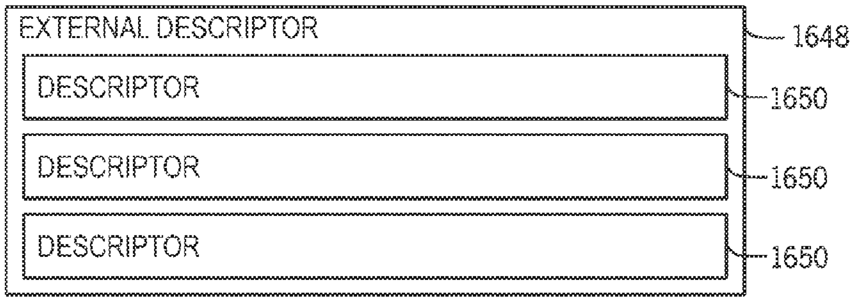

EXTERNAL DESCRIPTOR
DESCRIPTOR
DESCRIPTOR
DESCRIPTOR
1648
1650
1650
1650

FIG. 39

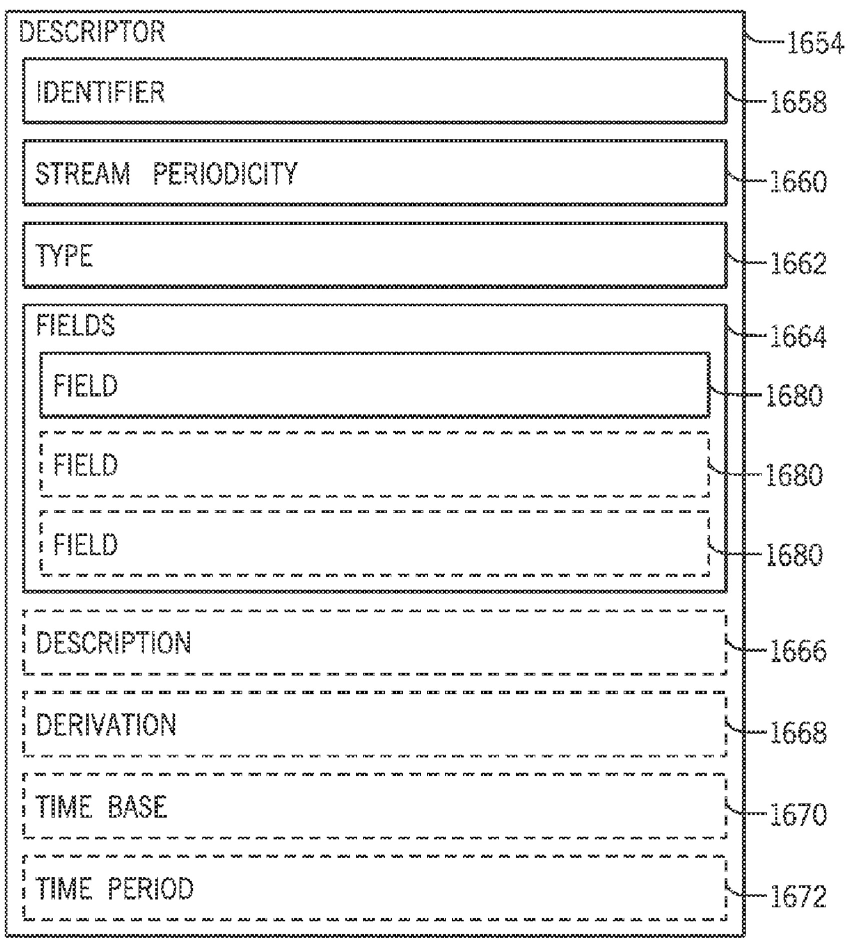

DESCRIPTOR
IDENTIFIER
STREAM PERIODICITY
TYPE
FIELDS
FIELD
FIELD
FIELD
DESCRIPTION
DERIVATION
TIME BASE
TIME PERIOD
1654
1658
1660
1662
1664
1680
1680
1680
1666
1668
1670
1672

FIG. 40

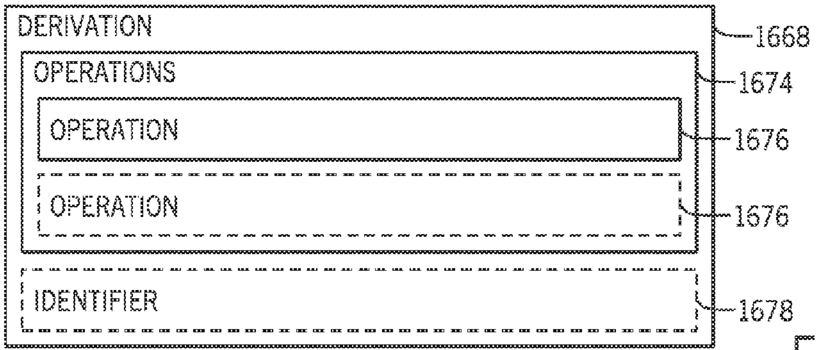

DERIVATION
OPERATIONS
OPERATION
OPERATION
IDENTIFIER
1668
1674
1676
1676
1678

FIG. 41

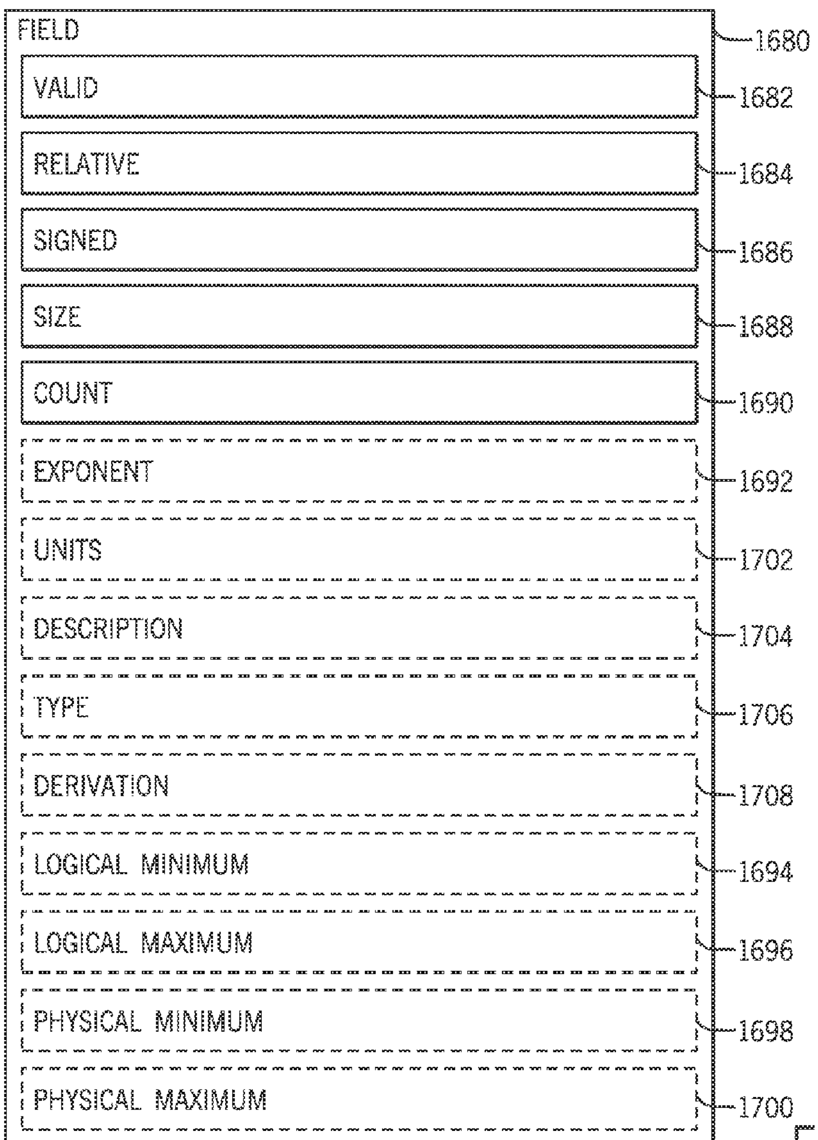

FIELD
VALID
RELATIVE
SIGNED
SIZE
COUNT
EXPONENT
UNITS
DESCRIPTION
TYPE
DERIVATION
LOGICAL MINIMUM
LOGICAL MAXIMUM
PHYSICAL MINIMUM
PHYSICAL MAXIMUM
1680
1682
1684
1686
1688
1690
1692
1702
1704
1706
1708
1694
1696
1698
1700

FIG. 42

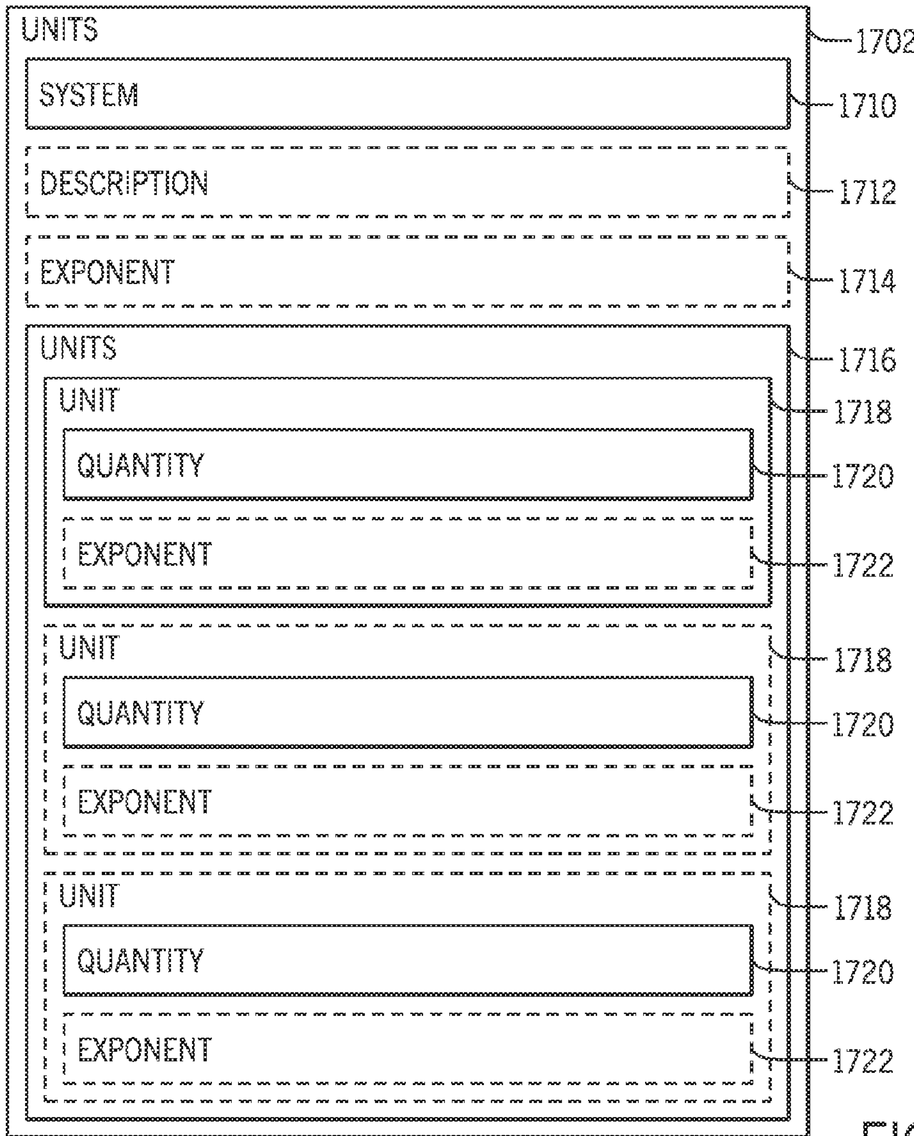

UNITS
1702
SYSTEM
1710
DESCRIPTION
1712
EXPONENT
1714
UNITS
1716
UNIT
1718
QUANTITY
1720
EXPONENT
1722
UNIT
1718
QUANTITY
1720
EXPONENT
1722
UNIT
1718
QUANTITY
1720
EXPONENT
1722

FIG. 43

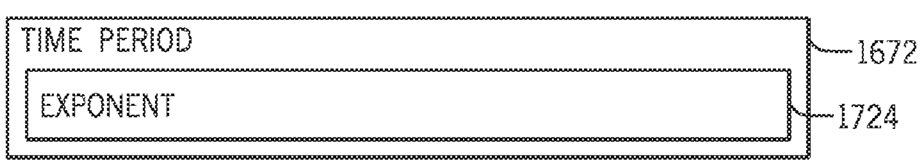

TIME PERIOD
1672
EXPONENT
1724

FIG. 44

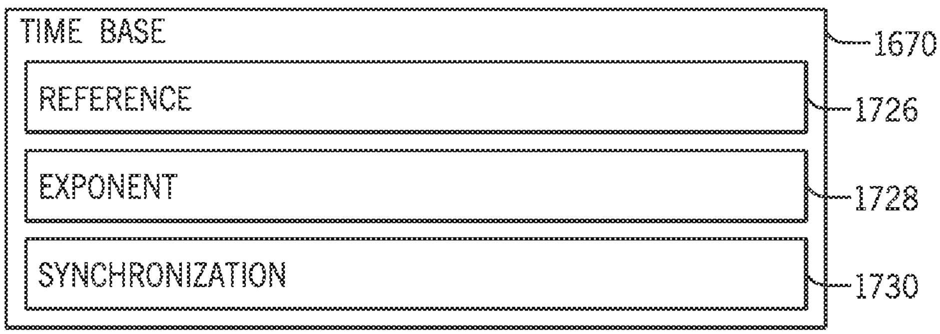

TIME BASE
1670
REFERENCE
1726
EXPONENT
1728
SYNCHRONIZATION
1730

FIG. 45

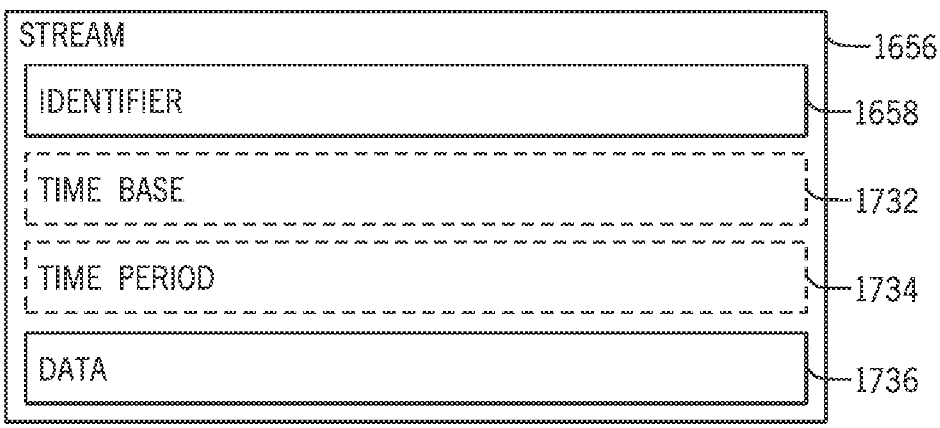
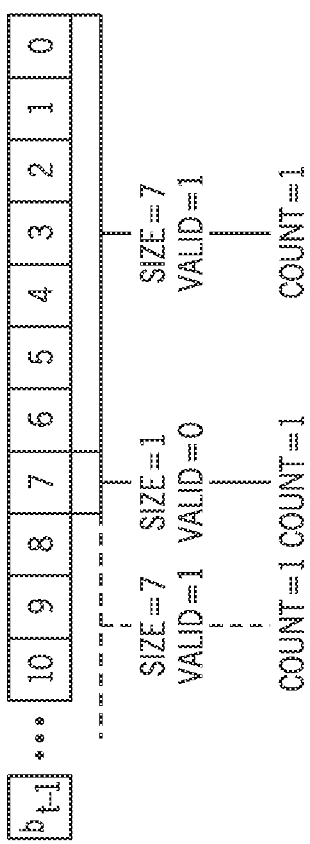
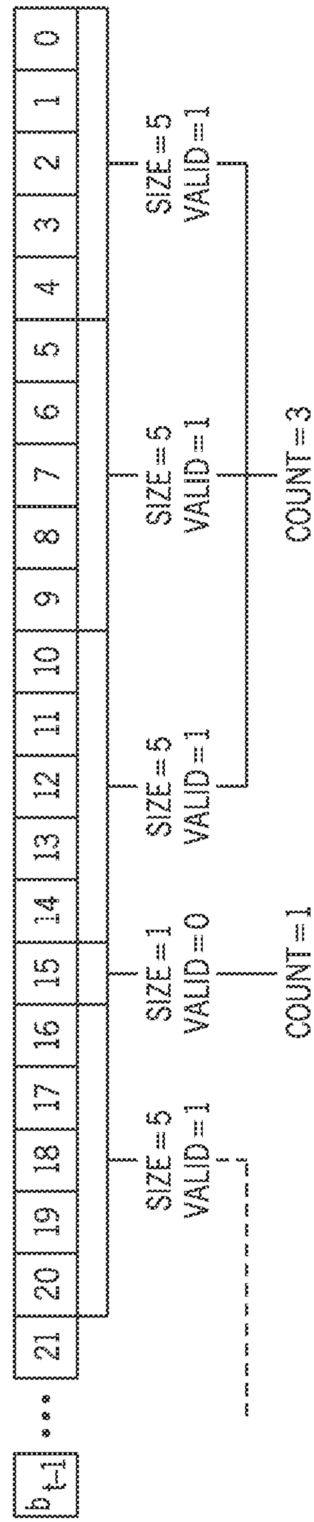

STREAM
1656
IDENTIFIER
1658
TIME BASE
1732
TIME PERIOD
1734
DATA
1736

FIG. 46



b t-1
10
9
8
7
6
5
4
3
2
1
0
SIZE = 7
VALID = 1
COUNT = 1
SIZE = 1
VALID = 0
COUNT = 1
SIZE = 7
VALID = 1
COUNT = 1

FIG. 47



b t-1
21
20
19
18
17
16
15
14
13
12
11
10
9
8
7
6
5
4
3
2
1
0
SIZE = 5
VALID = 1
SIZE = 1
VALID = 0
COUNT = 1
SIZE = 5
VALID = 1
SIZE = 5
VALID = 1
COUNT = 3
SIZE = 5
VALID = 1

FIG. 48

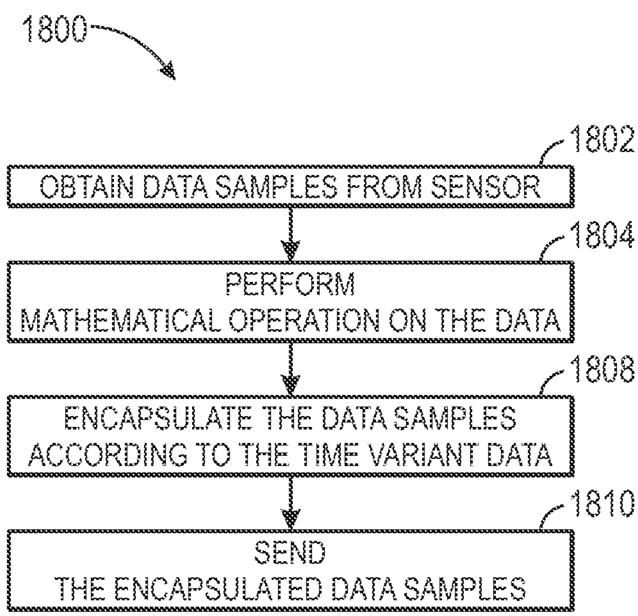

1800
1802
OBTAIN DATA SAMPLES FROM SENSOR
1804
PERFORM
MATHEMATICAL OPERATION ON THE DATA
1808
ENCAPSULATE THE DATA SAMPLES
ACCORDING TO THE TIME VARIANT DATA
1810
SEND
THE ENCAPSULATED DATA SAMPLES

FIG. 49

TIME VARIANT DATA PROFILE FOR A FABRIC NETWORK

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of Provisional Application Ser. No. 62/061,593, filed Oct. 8, 2014, entitled "FABRIC NETWORK," which is incorporated by reference herein in its entirety.

BACKGROUND

This disclosure relates data communication profiles for systems, devices, methods, and related computer program products for smart buildings, such as a smart home. This disclosure relates to a fabric network that couples electronic devices using one or more network types and a time variant data profile used to determine chronology of events of multiple devices in the home.

Some homes today are equipped with smart home networks to provide automated control of devices, appliances and systems, such as heating, ventilation, and air conditioning ("HVAC") systems, lighting systems, alarm systems, and home theater and entertainment systems. Smart home networks may include control panels that a person may use to input settings, preferences, and scheduling information that the smart home network uses to provide automated control the various devices, appliances and systems in the home. For example, a person may input a desired temperature and a schedule indicating when the person is away from home.

These networks may include various devices that are sleepy and/or have intermittent connection between each other. The data stored in each of these devices may then not be chronologically accurate if only using clock times of the devices while the devices are awake. Furthermore, it may be unclear how entries in data from different devices relate to each other in time when events between all the devices may not be linearly recorded.

This section is intended to introduce the reader to various aspects of art that may be related to various aspects of the present techniques, which are described and/or claimed below. This discussion is believed to be helpful in providing the reader with background information to facilitate a better understanding of the various aspects of the present disclosure. Accordingly, it should be understood that these statements are to be read in this light, and not as admissions of prior art.

SUMMARY

A summary of certain embodiments disclosed herein is set forth below. It should be understood that these aspects are presented merely to provide the reader with a brief summary of these certain embodiments and that these aspects are not intended to limit the scope of this disclosure. Indeed, this disclosure may encompass a variety of aspects that may not be set forth below.

Embodiments of the present disclosure relate to systems and methods a fabric network that includes one or more logical networks that enables devices connected to the fabric to communicate with each other using a list of protocols and/or profiles known to the devices. The communications between the devices may follow a typical message format that enables the devices to understand communications between the devices regardless of which logical networks the communicating devices are connected to in the fabric. Within the message format, a payload of data may be included for the receiving device to store and/or process. The format and the contents of the payload may vary according to a header (e.g., profile tag) within the payload that indicates a specific profile (including one or more protocols) and/or a type of message/action that is being sent according to the profile.

According to some embodiments, two or more devices in a fabric may communicate using various profiles. For example, in certain embodiments, a data management profile, a network provisioning profile, or a core profile (including status reporting protocols) that are available to devices connected to the fabric. Also, a time-variant data profile may be used for reporting and exchanging time-variant historical data among endpoints within a smart network. In some embodiments, at least a portion of the role of any device in the smart network is to observe and record the environment of which the device is a part. This observation and reporting is done over time and reporting those time-variant historical observations to other endpoints in the smart network. The time-variant data profile defines a set of constants and messages for exchanging these time-variant historical observations atop the bulk data transfer protocol. In some embodiments, this profile has an identified profile identifier that indicates that a communication includes data in the time-variant data profile.

Various refinements of the features noted above may exist in relation to various aspects of the present disclosure. Further features may also be incorporated in these various aspects as well. These refinements and additional features may exist individually or in any combination. For instance, various features discussed below in relation to one or more of the illustrated embodiments may be incorporated into any of the above-described aspects of the present disclosure alone or in any combination. The brief summary presented above is intended only to familiarize the reader with certain aspects and contexts of embodiments of the present disclosure without limitation to the claimed subject matter.

BRIEF DESCRIPTION OF THE DRAWINGS

Various aspects of this disclosure may be better understood upon reading the following detailed description and upon reference to the drawings in which:

FIG. **1** is a block diagram of an electronic device having that may be interconnected with other devices using a fabric network, in accordance with an embodiment;

FIG. **2** illustrates a block diagram of a home environment in which the general device of FIG. **1** may communicate with other devices via the fabric network, in accordance with an embodiment;

FIG. **3** illustrates a block diagram of an Open Systems Interconnection (OSI) model that characterizes a communication system for the home environment of FIG. **2**, in accordance with an embodiment;

FIG. **4** illustrates the fabric network having a single logical network topology, in accordance with an embodiment;

FIG. **5** illustrates the fabric network having a star network topology, in accordance with an embodiment;

FIG. **6** illustrates the fabric network having an overlapping networks topology, in accordance with an embodiment;

FIG. **7** illustrates a service communicating with one or more fabric networks, in accordance with an embodiment;

FIG. 8 illustrates two devices in a fabric network in communicative connection, in accordance with an embodiment;

FIG. 9 illustrates a unique local address format (ULA) that may be used to address devices in a fabric network, in accordance with an embodiment;

FIG. 10 illustrates a process for proxying periphery devices on a hub network, in accordance with an embodiment;

FIG. 11 illustrates a tag-length-value (TLV) packet that may be used to transmit data over the fabric network, in accordance with an embodiment;

FIG. 12 illustrates a general message protocol (GMP) that may be used to transmit data over the fabric network that may include the TLV packet of FIG. 11, in accordance with an embodiment;

FIG. 13 illustrates a message header field of the GMP of FIG. 12, in accordance with an embodiment;

FIG. 14 illustrates a key identifier field of the GMP of FIG. 12, in accordance with an embodiment;

FIG. 15 illustrates an application payload field of the GMP of FIG. 12, in accordance with an embodiment;

FIG. 16 illustrates a profile library that includes various profiles that may be used in the application payload field of FIG. 15;

FIG. 17 illustrates a status reporting schema that may be used to update status information in the fabric network, in accordance with an embodiment;

FIG. 18 illustrates a profile field of the status reporting schema of FIG. 17, in accordance with an embodiment;

FIG. 19 illustrates a protocol sequence that may be used to perform a software update between a client and a server, in accordance with an embodiment;

FIG. 20 illustrates an image query frame that may be used in the protocol sequence of FIG. 19, in accordance with an embodiment;

FIG. 21 illustrates a frame control field of the image query frame of FIG. 20, in accordance with an embodiment;

FIG. 22 illustrates a product specification field of the image query frame of FIG. 20, in accordance with an embodiment;

FIG. 23 illustrates a version specification field of the image query frame of FIG. 20, in accordance with an embodiment;

FIG. 24 illustrates a locale specification field of the image query frame of FIG. 20, in accordance with an embodiment;

FIG. 25 illustrates an integrity types supported field of the image query frame of FIG. 20, in accordance with an embodiment;

FIG. 26 illustrates an update schemes supported field of the image query frame of FIG. 20, in accordance with an embodiment;

FIG. 27 illustrates an image query response frame that may be used in the protocol sequence of FIG. 19, in accordance with an embodiment;

FIG. 28 illustrates a uniform resource identifier (URI) field of the image query response frame of FIG. 27, in accordance with an embodiment;

FIG. 29 illustrates a integrity specification field of the image query response frame of FIG. 27, in accordance with an embodiment;

FIG. 30 illustrates an update scheme field of the image query response frame of FIG. 27, in accordance with an embodiment;

FIG. 31 illustrates a communicative connection between a sender and a receiver in a bulk data transfer, in accordance with an embodiment;

FIG. 32 illustrates a SendInit message that may be used to initiate the communicative connection by the sender of FIG. 31, in accordance with an embodiment;

FIG. 33 illustrates a transfer control field of the SendInit message of FIG. 32, in accordance with an embodiment;

FIG. 34 illustrates a range control field of the SendInit message of FIG. 33, in accordance with an embodiment;

FIG. 35 illustrates a SendAccept message that may be used to accept a communicative connection proposed by the SendInit message of FIG. 32 sent by the sender of FIG. 32, in accordance with an embodiment;

FIG. 36 illustrates a SendReject message that may be used to reject a communicative connection proposed by the SendInit message of FIG. 32 sent by the sender of FIG. 32, in accordance with an embodiment;

FIG. 37 illustrates a ReceiveAccept message that may be used to accept a communicative connection proposed by the receiver of FIG. 32, in accordance with an embodiment;

FIG. 38 illustrates a streams structure of the used by a time variant data profile, in accordance with an embodiment;

FIG. 39 illustrates an External Descriptor structure that is an array of Descriptor elements, in accordance with an embodiment;

FIG. 40 illustrates a descriptor structure of the streams structure of FIG. 38, in accordance with an embodiment;

FIG. 41 illustrates a derivation structure of the descriptor structure of FIG. 40, in accordance with an embodiment;

FIG. 42 illustrates a field structure of the descriptor structure of FIG. 40, in accordance with an embodiment;

FIG. 43 illustrates a units structure of the field structure of FIG. 39, in accordance with an embodiment;

FIG. 44 illustrates a time period structure of the descriptor structure of FIG. 40, in accordance with an embodiment;

FIG. 45 illustrates a time base structure of the descriptor structure of FIG. 40, in accordance with an embodiment;

FIG. 46 illustrates a stream substructure of the streams structure of FIG. 38, in accordance with an embodiment;

FIG. 47 illustrates a flexible data arrangement of data that may be sent using the time variant data profile, in accordance with an embodiment;

FIG. 48 illustrates another flexible data arrangement of data that may be sent using the time variant data profile, in accordance with an embodiment; and

FIG. 49 illustrates a flow diagram of a process that may be used to generate encapsulated data samples for time variant data, in accordance with an embodiment.

DETAILED DESCRIPTION

One or more specific embodiments of the present disclosure will be described below. These described embodiments are only examples of the presently disclosed techniques. Additionally, in an effort to provide a concise description of these embodiments, features of an actual implementation may not be described in the specification. It should be appreciated that in the development of any such actual implementation, as in any engineering or design project, numerous implementation-specific decisions must be made to achieve the developers' specific goals, such as compliance with system-related and business-related constraints, which may vary from one implementation to another. Moreover, it should be appreciated that such a development effort might be complex and time consuming, but may nevertheless be a routine undertaking of design, fabrication, and manufacture for those of ordinary skill having the benefit of this disclosure.

When introducing elements of various embodiments of the present disclosure, the articles "a," "an," and "the" are intended to mean that there are one or more of the elements. The terms "comprising," "including," and "having" are intended to be inclusive and mean that there may be additional elements other than the listed elements. Additionally, it should be understood that references to "one embodiment" or "an embodiment" of the present disclosure are not intended to be interpreted as excluding the existence of additional embodiments that also incorporate the recited features.

Embodiments of the present disclosure relate generally to an efficient fabric network that may be used by devices and/or services communicating with each other in a home environment. Generally, consumers living in homes may find it useful to coordinate the operations of various devices within their home such that of their devices are operated efficiently. For example, a thermostat device may be used to detect a temperature of a home and coordinate the activity of other devices (e.g., lights) based on the detected temperature. In this example, the thermostat device may detect a temperature that may indicate that the temperature outside the home corresponds to daylight hours. The thermostat device may then convey to the light device that there may be daylight available to the home and that thus the light should turn off.

In addition to operating these devices efficiently, consumers generally prefer to use user-friendly devices that involve a minimum amount of set up or initialization. That is, consumers may generally prefer to purchase devices that are fully operational after performing a few number initialization steps that may be performed by almost any individual regardless of age or technical expertise.

With the foregoing in mind, to enable to effectively communicate data between each other within the home environment, the devices may use a fabric network that includes one or more logical networks to manage communication between the devices. That is, the efficient fabric network may enable numerous devices within a home to communicate with each other using one or more logical networks. The communication network may support Internet Protocol version 6 (IPv6) communications such that each connected device may have a unique local address (LA). Moreover, to enable each device to integrate with a home, it may be useful for each device to communicate within the network using low amounts of power. That is, by enabling devices to communicate using low power, the devices may be placed anywhere in a home without being coupled to a continuous power source (e.g., battery-powered).

I. Fabric Introduction

By way of introduction, FIG. **1** illustrates an example of a general device **10** that may that may communicate with other like devices within a home environment. In one embodiment, the device **10** may include one or more sensors **12**, a user-interface component **14**, a power supply **16** (e.g., including a power connection and/or battery), a network interface **18**, a processor **20**, and the like. Particular sensors **12**, user-interface components **14**, and power-supply configurations may be the same or similar with each devices **10**. However, it should be noted that in some embodiments, each device **10** may include particular sensors **12**, user-interface components **14**, power-supply configurations, and the like based on a device type or model.

The sensors **12**, in certain embodiments, may detect various properties such as acceleration, temperature, humidity, water, supplied power, proximity, external motion, device motion, sound signals, ultrasound signals, light signals, fire, smoke, carbon monoxide, global-positioning-satellite (GPS) signals, radio-frequency (RF), other electromagnetic signals or fields, or the like. As such, the sensors **12** may include temperature sensor(s), humidity sensor(s), hazard-related sensor(s) or other environmental sensor(s), accelerometer(s), microphone(s), optical sensors up to and including camera(s) (e.g., charged coupled-device or video cameras), active or passive radiation sensors, GPS receiver(s) or radiofrequency identification detector(s). While FIG. **1** illustrates an embodiment with a single sensor, many embodiments may include multiple sensors. In some instances, the device **10** may includes one or more primary sensors and one or more secondary sensors. Here, the primary sensor(s) may sense data central to the core operation of the device (e.g., sensing a temperature in a thermostat or sensing smoke in a smoke detector), while the secondary sensor(s) may sense other types of data (e.g., motion, light or sound), which can be used for energy-efficiency objectives or smart-operation objectives.

One or more user-interface components **14** in the device **10** may receive input from the user and/or present information to the user. The user-interface component **14** may also include one or more user-input components that may receive information from the user. The received input may be used to determine a setting. In certain embodiments, the user-input components may include a mechanical or virtual component that responds to the user's motion. For example, the user can mechanically move a sliding component (e.g., along a vertical or horizontal track) or rotate a rotatable ring (e.g., along a circular track), the user's motion along a touchpad may be detected, or motions/gestures may be detected using a contactless gesture detection sensor (e.g., infrared sensor or camera). Such motions may correspond to a setting adjustment, which can be determined based on an absolute position of a user-interface component **104** or based on a displacement of a user-interface components **104** (e.g., adjusting a setpoint temperature by 1 degree F. for every 10° rotation of a rotatable-ring component). Physically and virtually movable user-input components can allow a user to set a setting along a portion of an apparent continuum. Thus, the user may not be confined to choose between two discrete options (e.g., as would be the case if up and down buttons were used) but can quickly and intuitively define a setting along a range of possible setting values. For example, a magnitude of a movement of a user-input component may be associated with a magnitude of a setting adjustment, such that a user may dramatically alter a setting with a large movement or finely tune a setting with s small movement.

The user-interface components **14** may also include one or more buttons (e.g., up and down buttons), a keypad, a number pad, a switch, a microphone, and/or a camera (e.g., to detect gestures). In one embodiment, the user-input component **14** may include a click-and-rotate annular ring component that may enable the user to interact with the component by rotating the ring (e.g., to adjust a setting) and/or by clicking the ring inwards (e.g., to select an adjusted setting or to select an option). In another embodiment, the user-input component **14** may include a camera that may detect gestures (e.g., to indicate that a power or alarm state of a device is to be changed). In some instances, the device **10** may have one primary input component, which may be used to set various types of settings. The user-interface components **14** may also be configured to present information to a user via, e.g., a visual display (e.g., a thin-film-transistor display or organic light-emitting-diode display) and/or an audio speaker.

The power-supply component **16** may include a power connection and/or a local battery. For example, the power connection may connect the device **10** to a power source such as a line voltage source. In some instances, an AC power source can be used to repeatedly charge a (e.g., rechargeable) local battery, such that the battery may be used later to supply power to the device **10** when the AC power source is not available. In certain embodiments, the power supply component **16** may include intermittent or reduced power connections that may be less than that provided via an AC plug in the home. In certain embodiments, devices with batteries and/or intermittent or reduced power may be operated as "sleepy devices" that alternate between an online/awake state and an offline/sleep state to reduce power consumption.

The network interface **18** may include one or more components that enable the device **10** to communicate between devices using one or more logical networks within the fabric network. In one embodiment, the network interface **18** may communicate using an efficient network layer as part of its Open Systems Interconnection (OSI) model. In certain embodiments, one component of the network interface **18** may communicate with one logical network (e.g., WiFi) and another component of the network interface may communicate with another logical network (e.g., 802.15.4). In other words, the network interface **18** may enable the device **10** to wirelessly communicate via multiple IPv6 networks. As such, the network interface **18** may include a wireless card, Ethernet port, and/or other suitable transceiver connections.

The processor **20** may support one or more of a variety of different device functionalities. As such, the processor **20** may include one or more processors configured and programmed to carry out and/or cause to be carried out one or more of the functionalities described herein. In one embodiment, the processor **20** may include general-purpose processors carrying out computer code stored in local memory (e.g., flash memory, hard drive, random access memory), special-purpose processors or application-specific integrated circuits, other types of hardware/firmware/software processing platforms, and/or some combination thereof. Further, the processor **20** may be implemented as localized versions or counterparts of algorithms carried out or governed remotely by central servers or cloud-based systems, such as by virtue of running a Java virtual machine (JVM) that executes instructions provided from a cloud server using Asynchronous Javascript and XML (AJAX) or similar protocols. By way of example, the processor **20** may detect when a location (e.g., a house or room) is occupied, up to and including whether it is occupied by a specific person or is occupied by a specific number of people (e.g., relative to one or more thresholds). In one embodiment, this detection can occur, e.g., by analyzing microphone signals, detecting user movements (e.g., in front of a device), detecting openings and closings of doors or garage doors, detecting wireless signals, detecting an IP address of a received signal, detecting operation of one or more devices within a time window, or the like. Moreover, the processor **20** may include image recognition technology to identify particular occupants or objects.

In some instances, the processor **20** may predict desirable settings and/or implement those settings. For example, based on presence detection, the processor **20** may adjust device settings to, e.g., conserve power when nobody is home or in a particular room or to accord with user preferences (e.g., general at-home preferences or user-specific preferences). As another example, based on the detection of a particular person, animal or object (e.g., a child, pet or lost object), the processor **20** may initiate an audio or visual indicator of where the person, animal or object is or may initiate an alarm or security feature if an unrecognized person is detected under certain conditions (e.g., at night or when lights are off).

In some instances, devices may interact with each other such that events detected by a first device influences actions of a second device using one or more common profiles between the devices. For example, a first device can detect that a user has pulled into a garage (e.g., by detecting motion in the garage, detecting a change in light in the garage or detecting opening of the garage door). The first device can transmit this information to a second device via the fabric network, such that the second device can, e.g., adjust a home temperature setting, a light setting, a music setting, and/or a security-alarm setting. As another example, a first device can detect a user approaching a front door (e.g., by detecting motion or sudden light pattern changes). The first device may cause a general audio or visual signal to be presented (e.g., such as sounding of a doorbell) or cause a location-specific audio or visual signal to be presented (e.g., to announce the visitor's presence within a room that a user is occupying).

With the foregoing in mind, FIG. **2** illustrates a block diagram of a home environment **30** in which the device **10** of FIG. **1** may communicate with other devices via the fabric network. The depicted home environment **30** may include a structure **32** such as a house, office building, garage, or mobile home. It will be appreciated that devices can also be integrated into a home environment that does not include an entire structure **32**, such as an apartment, condominium, office space, or the like. Further, the home environment **30** may control and/or be coupled to devices outside of the actual structure **32**. Indeed, several devices in the home environment **30** need not physically be within the structure **32** at all. For example, a device controlling a pool heater **34** or irrigation system **36** may be located outside of the structure **32**.

The depicted structure **32** includes multiple rooms **38**, separated at least partly from each other via walls **40**. The walls **40** can include interior walls or exterior walls. Each room **38** can further include a floor **42** and a ceiling **44**. Devices can be mounted on, integrated with and/or supported by the wall **40**, the floor **42**, or the ceiling **44**.

The home environment **30** may include multiple devices, including intelligent, multi-sensing, network-connected devices that may integrate seamlessly with each other and/or with cloud-based server systems to provide any of a variety of useful home objectives. One, more or each of the devices illustrated in the home environment **30** may include one or more sensors **12**, a user interface **14**, a power supply **16**, a network interface **18**, a processor **20** and the like.

Example devices **10** may include a network-connected thermostat **46** that may detect ambient climate characteristics (e.g., temperature and/or humidity) and control a heating, ventilation and air-conditioning (HVAC) system **48**. Another example device **10** may include a hazard detection unit **50** that can detect the presence of a hazardous substance and/or a hazardous condition in the home environment **30** (e.g., smoke, fire, or carbon monoxide). Additionally, entryway interface devices **52**, which can be termed a "smart doorbell", can detect a person's approach to or departure from a location, control audible functionality, announce a person's approach or departure via audio or visual means, or control settings on a security system (e.g., to activate or deactivate the security system).

In certain embodiments, the device **10** may include a light switch **54** that may detect ambient lighting conditions, detect room-occupancy states, and control a power and/or dim state of one or more lights. In some instances, the light switches **54** may control a power state or speed of a fan, such as a ceiling fan.

Additionally, wall plug interfaces **56** may detect occupancy of a room or enclosure and control supply of power to one or more wall plugs (e.g., such that power is not supplied to the plug if nobody is at home). The device **10** within the home environment **30** may further include an appliance **58**, such as refrigerators, stoves and/or ovens, televisions, washers, dryers, lights (inside and/or outside the structure **32**), stereos, intercom systems, garage-door openers, floor fans, ceiling fans, whole-house fans, wall air conditioners, pool heaters **34**, irrigation systems **36**, security systems, and so forth. While descriptions of FIG. **2** may identify specific sensors and functionalities associated with specific devices, it will be appreciated that any of a variety of sensors and functionalities (such as those described throughout the specification) may be integrated into the device **10**.

In addition to containing processing and sensing capabilities, each of the example devices described above may be capable of data communications and information sharing with any other device, as well as to any cloud server or any other device that is network-connected anywhere in the world. In one embodiment, the devices **10** may send and receive communications via a fabric network discussed below. In one embodiment, fabric may enable the devices **10** to communicate with each other via one or more logical networks. As such, certain devices may serve as wireless repeaters and/or may function as bridges between devices, services, and/or logical networks in the home environment that may not be directly connected (i.e., one hop) to each other.

In one embodiment, a wireless router **60** may further communicate with the devices **10** in the home environment **30** via one or more logical networks (e.g., WiFi). The wireless router **60** may then communicate with the Internet **62** or other network such that each device **10** may communicate with a remote service or a cloud-computing system **64** through the Internet **62**. The cloud-computing system **64** may be associated with a manufacturer, support entity or service provider associated with a particular device **10**. As such, in one embodiment, a user may contact customer support using a device itself rather than using some other communication means such as a telephone or Internet-connected computer. Further, software updates can be automatically sent from the cloud-computing system **64** or devices in the home environment **30** to other devices in the fabric (e.g., when available, when purchased, when requested, or at routine intervals).

By virtue of network connectivity, one or more of the devices **10** may further allow a user to interact with the device even if the user is not proximate to the device. For example, a user may communicate with a device using a computer (e.g., a desktop computer, laptop computer, or tablet) or other portable electronic device (e.g., a smartphone) **66**. A webpage or application may receive communications from the user and control the device **10** based on the received communications. Moreover, the webpage or application may present information about the device's operation to the user. For example, the user can view a current setpoint temperature for a device and adjust it using a computer that may be connected to the Internet **62**. In this example, the thermostat **46** may receive the current setpoint temperature view request via the fabric network via one or more underlying logical networks.

In certain embodiments, the home environment **30** may also include a variety of non-communicating legacy appliances **68**, such as old conventional washer/dryers, refrigerators, and the like which can be controlled, albeit coarsely (ON/OFF), by virtue of the wall plug interfaces **56**. The home environment **30** may further include a variety of partially communicating legacy appliances **70**, such as infrared (IR) controlled wall air conditioners or other IR-controlled devices, which can be controlled by IR signals provided by the hazard detection units **50** or the light switches **54**.

As mentioned above, each of the example devices **10** described above may form a portion of a fabric network. Generally, the fabric network may be part of an Open Systems Interconnection (OSI) model **90** as depicted in FIG. **4**. The OSI model **90** illustrates functions of a communication system with respect to abstraction layers. That is, the OSI model may specify a networking framework or how communications between devices may be implemented. In one embodiment, the OSI model may include six layers: a physical layer **92**, a data link layer **94**, a network layer **96**, a transport layer **98**, a platform layer **100**, and an application layer **102**. Generally, each layer in the OSI model **90** may serve the layer above it and may be served by the layer below it.

Keeping this in mind, the physical layer **92** may provide hardware specifications for devices that may communicate with each other. As such, the physical layer **92** may establish how devices may connect to each other, assist in managing how communication resources may be shared between devices, and the like.

The data link layer **94** may specify how data may be transferred between devices. Generally, the data link layer **94** may provide a way in which data packets being transmitted may be encoded and decoded into bits as part of a transmission protocol.

The network layer **96** may specify how the data being transferred to a destination node is routed. The network layer **96** may also provide a security protocol that may maintain the integrity of the data being transferred. The efficient network layer discussed above corresponds to the network layer **96**. In certain embodiments, the network layer **96** may be completely independent of the platform layer **100** and include any suitable IPv6 network type (e.g., WiFi, Ethernet, HomePlug, 802.15.4, etc).

The transport layer **98** may specify a transparent transfer of the data from a source node to a destination node. The transport layer **98** may also control how the transparent transfer of the data remains reliable. As such, the transport layer **98** may be used to verify that data packets intended to transfer to the destination node indeed reached the destination node. Example protocols that may be employed in the transport layer **98** may include Transmission Control Protocol (TCP) and User Datagram Protocol (UDP).

The platform layer **100** includes the fabric network and establishes connections between devices according to the protocol specified within the transport layer **98** and may be agnostic of the network type used in the network layer **96**. The platform layer **100** may also translate the data packets into a form that the application layer **102** may use. The application layer **102** may support a software application that may directly interface with the user. As such, the application layer **102** may implement protocols defined by the software application. For example, the software application may provide serves such as file transfers, electronic mail, and the like.

II. Fabric Device Interconnection

As discussed above, a fabric may be implemented using one or more suitable communications protocols, such as IPv6 protocols. In fact, the fabric may be partially or completely agnostic to the underlying technologies (e.g., network types or communication protocols) used to implement the fabric. Within the one or more communications protocols, the fabric may be implemented using one or more network types used to communicatively couple electrical devices using wireless or wired connections. For example, certain embodiments of the fabric may include Ethernet, WiFi, 802.15.4, ZigBee®, ISA100.11a, WirelessHART, MiWi™, power-line networks, and/or other suitable network types. Within the fabric devices (e.g., nodes) can exchange packets of information with other devices (e.g., nodes) in the fabric, either directly or via intermediary nodes, such as intelligent thermostats, acting as IP routers. These nodes may include manufacturer devices (e.g., thermostats and smoke detectors) and/or customer devices (e.g., phones, tablets, computers, etc.). Additionally, some devices may be "always on" and continuously powered using electrical connections. Other devices may have partially reduced power usage (e.g., medium duty cycle) using a reduced/intermittent power connection, such as a thermostat or doorbell power connection. Finally, some devices may have a short duty cycle and run solely on battery power. In other words, in certain embodiments, the fabric may include heterogeneous devices that may be connected to one or more sub-networks according to connection type and/or desired power usage. FIGS. 4-6 illustrate three embodiments that may be used to connect electrical devices via one or more sub-networks in the fabric.

A. Single Network Topology

FIG. **4** illustrates an embodiment of the fabric **1000** having a single network topology. As illustrated, the fabric **1000** includes a single logical network **1002**. The network **1002** could include Ethernet, WiFi, 802.15.4, power-line networks, and/or other suitable network types in the IPv6 protocols. In fact, in some embodiments where the network **1002** includes a WiFi or Ethernet network, the network **1002** may span multiple WiFi and/or Ethernet segments that are bridged at a link layer.

The network **1002** includes one or more nodes **1004**, **1006**, **1008**, **1010**, **1012**, **1014**, and **1016**, referred to collectively as **1004-1016**. Although the illustrated network **1002** includes seven nodes, certain embodiments of the network **1002** may include one or more nodes interconnected using the network **1002**. Moreover, if the network **1002** is a WiFi network, each of the nodes **1004-1016** may be interconnected using the node **1016** (e.g., WiFi router) and/or paired with other nodes using WiFi Direct (i.e., WiFi P2P).

B. Star Network Topology

FIG. **5** illustrates an alternative embodiment of fabric **1000** as a fabric **1018** having a star network topology. The fabric **1018** includes a hub network **1020** that joins together two periphery networks **1022** and **1024**. The hub network **1020** may include a home network, such as WiFi/Ethernet network or power line network. The periphery networks **1022** and **1024** may additional network connection types different of different types than the hub network **1020**. For example, in some embodiments, the hub network **1020** may be a WiFi/Ethernet network, the periphery network **1022** may include an 802.15.4 network, and the periphery network **1024** may include a power line network, a ZigBee® network, a ISA100.11a network, a WirelessHART, network, or a MiWi™ network. Moreover, although the illustrated embodiment of the fabric **1018** includes three networks, certain embodiments of the fabric **1018** may include any number of networks, such as 2, 3, 4, 5, or more networks. In fact, some embodiments of the fabric **1018** include multiple periphery networks of the same type.

Although the illustrated fabric **1018** includes fourteen nodes, each referred to individually by reference numbers **1024-1052**, respectively, it should be understood that the fabric **1018** may include any number of nodes. Communication within each network **1020**, **1022**, or **1024**, may occur directly between devices and/or through an access point, such as node **1042** in a WiFi/Ethernet network. Communications between periphery network **1022** and **1024** passes through the hub network **1020** using inter-network routing nodes. For example, in the illustrated embodiment, nodes **1034** and **1036** are be connected to the periphery network **1022** using a first network connection type (e.g., 802.15.4) and to the hub network **1020** using a second network connection type (e.g., WiFi) while the node **1044** is connected to the hub network **1020** using the second network connection type and to the periphery network **1024** using a third network connection type (e.g., power line). For example, a message sent from node **1026** to node **1052** may pass through nodes **1028**, **1030**, **1032**, **1036**, **1042**, **1044**, **1048**, and **1050** in transit to node **1052**.

C. Overlapping Networks Topology

FIG. **6** illustrates an alternative embodiment of the fabric **1000** as a fabric **1054** having an overlapping networks topology. The fabric **1054** includes networks **1056** and **1058**. As illustrated, each of the nodes **1062**, **1064**, **1066**, **1068**, **1070**, and **1072** may be connected to each of the networks. In other embodiments, the node **1072** may include an access point for an Ethernet/WiFi network rather than an end point and may not be present on either the network **1056** or network **1058**, whichever is not the Ethernet/WiFi network. Accordingly, a communication from node **1062** to node **1068** may be passed through network **1056**, network **1058**, or some combination thereof. In the illustrated embodiment, each node can communicate with any other node via any network using any network desired. Accordingly, unlike the star network topology of FIG. **5**, the overlapping networks topology may communicate directly between nodes via any network without using inter-network routing.

D. Fabric Network Connection to Services

In addition to communications between devices within the home, a fabric (e.g., fabric **1000**) may include services that may be located physically near other devices in the fabric or physically remote from such devices. The fabric connects to these services through one or more service end points. FIG. **7** illustrates an embodiment of a service **1074** communicating with fabrics **1076**, **1078**, and **1080**. The service **1074** may include various services that may be used by devices in fabrics **1076**, **1078**, and/or **1080**. For example, in some embodiments, the service **1074** may be a time of day service that supplies a time of day to devices, a weather service to provide various weather data (e.g., outside temperature, sunset, wind information, weather forecast, etc.), an echo service that "pings" each device, data management services, device management services, and/or other suitable services. As illustrated, the service **1074** may include a server **1082** (e.g., web server) that stores/accesses relevant data and passes the information through a service end point **1084** to one or more end points **1086** in a fabric, such as fabric **1076**. Although the illustrated embodiment only includes three fabrics with a single server **1082**, it should be appreciated that the service **1074** may connect to any number of fabrics and may include servers in addition to the server **1082** and/or connections to additional services.

In certain embodiments, the service **1074** may also connect to a consumer device **1088**, such as a phone, tablet, and/or computer. The consumer device **1088** may be used to connect to the service **1074** via a fabric, such as fabric **1076**, an Internet connection, and/or some other suitable connection method. The consumer device **1088** may be used to access data from one or more end points (e.g., electronic devices) in a fabric either directly through the fabric or via the service **1074**. In other words, using the service **1074**, the consumer device **1088** may be used to access/manage devices in a fabric remotely from the fabric.

E. Communication Between Devices in a Fabric

As discussed above, each electronic device or node may communicate with any other node in the fabric, either directly or indirectly depending upon fabric topology and network connection types. Additionally, some devices (e.g., remote devices) may communicate through a service to communicate with other devices in the fabric. FIG. **8** illustrates an embodiment of a communication **1090** between two devices **1092** and **1094**. The communication **1090** may span one or more networks either directly or indirectly through additional devices and/or services, as described above. Additionally, the communication **1090** may occur over an appropriate communication protocol, such as IPv6, using one or more transport protocols. For example, in some embodiments the communication **1090** may include using the transmission control protocol (TCP) and/or the user datagram protocol (UDP). In some embodiments, the device **1092** may transmit a first signal **1096** to the device **1094** using a connectionless protocol (e.g., UDP). In certain embodiments, the device **1092** may communicate with the device **1094** using a connection-oriented protocol (e.g., TCP). Although the illustrated communication **1090** is depicted as a bi-directional connection, in some embodiments, the communication **1090** may be a uni-directional broadcast.

i. Unique Local Address

As discussed above, data transmitted within a fabric received by a node may be redirected or passed through the node to another node depending on the desired target for the communication. In some embodiments, the transmission of the data may be intended to be broadcast to all devices. In such embodiments, the data may be retransmitted without further processing to determine whether the data should be passed along to another node. However, some data may be directed to a specific endpoint. To enable addressed messages to be transmitted to desired endpoints, nodes may be assigned identification information.

Each node may be assigned a set of link-local addresses (LLA), one assigned to each network interface. These LLAs may be used to communicate with other nodes on the same network. Additionally, the LLAs may be used for various communication procedures, such as IPv6 Neighbor Discovery Protocol. In addition to LLAs, each node is assigned a unique local address (ULA).

FIG. **9** illustrates an embodiment of a unique local address (ULA) **1098** that may be used to address each node in the fabric. In certain embodiments, the ULA **1098** may be formatted as an IPv6 address format containing 128 bits divided into a global ID **1100**, a subnet ID **1102**, and an interface ID **1104**. The global ID **1100** includes 40 bits and the subnet ID **1102** includes 16 bits. The global ID **1100** and subnet ID **1102** together form a fabric ID **1103** for the fabric.

The fabric ID **1103** is a unique 64-bit identifier used to identify a fabric. The fabric ID **1103** may be generated at creation of the associated fabric using a pseudo-random algorithm. For example, the pseudo-random algorithm may 1) obtain the current time of day in 64-bit NTP format, 2) obtain the interface ID **1104** for the device, 3) concatenate the time of day with the interface ID **1104** to create a key, 4) compute and SHA-1 digest on the key resulting in 160 bits, 5) use the least significant 40 bits as the global ID **1100**, and 6) concatenate the ULA and set the least significant bit to 1 to create the fabric ID **1103**. In certain embodiments, once the fabric ID **1103** is created with the fabric, the fabric ID **1103** remains until the fabric is dissolved.

The global ID **1100** identifies the fabric to which the node belongs. The subnet ID **1102** identifies logical networks within the fabric. The subnet ID **1102** may be assigned monotonically starting at one with the addition of each new logical network to the fabric. For example, a WiFi network may be identified with a hex value of 0x01, and a later connected 802.15.4 network may be identified with a hex value of 0x02 continuing on incrementally upon the connection of each new network to the fabric.

Finally, the ULA **1098** includes an interface ID **1104** that includes 64 bits. The interface ID **1104** may be assigned using a globally-unique 64-bit identifier according to the IEEE EUI-64 standard. For example, devices with IEEE 802 network interfaces may derive the interface ID **1104** using a burned-in MAC address for the devices "primary interface." In some embodiments, the designation of which interface is the primary interface may be determined arbitrarily. In other embodiments, an interface type (e.g., WiFi) may be deemed the primary interface, when present. If the MAC address for the primary interface of a device is 48 bits rather than 64-bit, the 48-bit MAC address may be converted to a EUI-64 value via encapsulation (e.g., organizationally unique identifier encapsulating). In consumer devices (e.g., phones or computers), the interface ID **1104** may be assigned by the consumer devices' local operating systems.

ii. Routing Transmissions Between Logical Networks

As discussed above in relation to a star network topology, inter-network routing may occur in communication between two devices across logical networks. In some embodiments, inter-network routing is based on the subnet ID **1102**. Each inter-networking node (e.g., node **1034** of FIG. **5**) may maintain a list of other routing nodes (e.g., node B **14** of FIG. **5**) on the hub network **1020** and their respective attached periphery networks (e.g., periphery network **1024** of FIG. **5**). When a packet arrives addressed to a node other than the routing node itself, the destination address (e.g., address for node **1052** of FIG. **5**) is compared to the list of network prefixes and a routing node (e.g., node **1044**) is selected that is attached to the desired network (e.g., periphery network **1024**). The packet is then forwarded to the selected routing node. If multiple nodes (e.g., **1034** and **1036**) are attached to the same periphery network, routing nodes are selected in an alternating fashion.

Additionally, inter-network routing nodes may regularly transmit Neighbor Discovery Protocol (NDP) router advertisement messages on the hub network to alert consumer devices to the existence of the hub network and allow them to acquire the subnet prefix. The router advertisements may include one or more route information options to assist in routing information in the fabric. For example, these route information options may inform consumer devices of the existence of the periphery networks and how to route packets the periphery networks.

In addition to, or in place of route information options, routing nodes may act as proxies to provide a connection between consumer devices and devices in periphery networks, such as the process **1105** as illustrated in FIG. **10**. As illustrated, the process **1105** includes each periphery network device being assigned a virtual address on the hub network by combining the subnet ID **1102** with the interface ID **1104** for the device on the periphery network (block **1106**). To proxy using the virtual addresses, routing nodes maintain a list of all periphery nodes in the fabric that are directly reachable via one of its interfaces (block **1108**). The routing nodes listen on the hub network for neighbor solicitation messages requesting the link address of a periphery node using its virtual address (block **1110**). Upon receiving such a message, the routing node attempts to assign the virtual address to its hub interface after a period of time (block **1112**). As part of the assignment, the routing node performs duplicate address detection so as to block proxying of the virtual address by more than one routing node. After the assignment, the routing node responds to the neighbor solicitation message and receives the packet (block **1114**). Upon receiving the packet, the routing node rewrites the destination address to be the real address of the periphery node (block **1116**) and forwards the message to the appropriate interface (block **1118**).

iii. Consumer Devices Connecting to a Fabric

To join a fabric, a consumer device may discover an address of a node already in the fabric that the consumer device wants to join. Additionally, if the consumer device has been disconnected from a fabric for an extended period of time may need to rediscover nodes on the network if the fabric topology/layout has changed. To aid in discovery/rediscovery, fabric devices on the hub network may publish Domain Name System-Service Discovery (DNS-SD) records via mDNS that advertise the presence of the fabric and provide addresses to the consumer device

III. Data Transmitted in the Fabric

After creation of a fabric and address creation for the nodes, data may be transmitted through the fabric. Data passed through the fabric may be arranged in a format common to all messages and/or common to specific types of conversations in the fabric. In some embodiments, the message format may enable one-to-one mapping to JavaScript Object Notation (JSON) using a TLV serialization format discussed below. Additionally, although the following data frames are described as including specific sizes, it should be noted that lengths of the data fields in the data frames may be varied to other suitable bit-lengths.

It should be understood that each of the following data frames, profiles, and/or formats discussed below may be stored in memory (e.g., memory of the device **10**) prior to and/or after transmission of a message. In other words, although the data frame, profiles, and formats may be generally discussed as transmissions of data, they may also be physically stored (e.g., in a buffer) before, during, and/or after transmission of the data frame, profiles, and/or formats. Moreover, the following data frames, profiles, schemas, and/or formats may be stored on a non-transitory, computer-readable medium that allows an electronic device to access the data frames, profiles, schemas, and/or formats. For example, instructions for formatting the data frames, profiles, schemas, and/or formats may be stored in any suitable computer-readable medium, such as in memory for the device **10**, memory of another device, a portable memory device (e.g., compact disc, flash drive, etc.), or other suitable physical device suitable for storing the data frames, profiles, schemas, and/or formats.

A. Security

Along with data intended to be transferred, the fabric may transfer the data with additional security measures such as encryption, message integrity checks, and digital signatures. In some embodiments, a level of security supported for a device may vary according to physical security of the device and/or capabilities of the device. In certain embodiments, messages sent between nodes in the fabric may be encrypted using the Advanced Encryption Standard (AES) block cipher operating in counter mode (AES-CTR) with a 128-bit key. As discussed below, each message contains a 32-bit message id. The message id may be combined with a sending nodes id to form a nonce for the AES-CTR algorithm. The 32-bit counter enables 4 billion messages to be encrypted and sent by each node before a new key is negotiated.

In some embodiments, the fabric may insure message integrity using a message authentication code, such as HMAC-SHA-1, that may be included in each encrypted message. In some embodiments, the message authentication code may be generated using a 160-bit message integrity key that is paired one-to-one with the encryption key. Additionally, each node may check the message id of incoming messages against a list of recently received ids maintained on a node-by-node basis to block replay of the messages.

B. Tag Length Value (TLV) Formatting

To reduce power consumption, it is desirable to send at least a portion of the data sent over the fabric that compactly while enabling the data containers to flexibly represents data that accommodates skipping data that is not recognized or understood by skipping to the next location of data that is understood within a serialization of the data. In certain embodiments, tag-length-value (TLV) formatting may be used to compactly and flexibly encode/decode data. By storing at least a portion of the transmitted data in TLV, the data may be compactly and flexibly stored/sent along with low encode/decode and memory overhead, as discussed below in reference to Table 7. In certain embodiments, TLV may be used for some data as flexible, extensible data, but other portions of data that is not extensible may be stored and sent in an understood standard protocol data unit (PDU).

Data formatted in a TLV format may be encoded as TLV elements of various types, such as primitive types and container types. Primitive types include data values in certain formats, such as integers or strings. For example, the TLV format may encode: 1, 2, 3, 4, or 8 byte signed/unsigned integers, UTF-8 strings, byte strings, single/double-precision floating numbers (e.g., IEEE 754-1985 format), boolean, null, and other suitable data format types. Container types include collections of elements that are then sub-classified as container or primitive types. Container types may be classified into various categories, such as dictionaries, arrays, paths or other suitable types for grouping TLV elements, known as members. A dictionary is a collection of members each having distinct definitions and unique tags within the dictionary. An array is an ordered collection of members with implied definitions or no distinct definitions. A path is an ordered collection of members that described how to traverse a tree of TLV elements.

As illustrated in FIG. **11**, an embodiment of a TLV packet **1120** includes three data fields: a tag field **1122**, a length field **1124**, and a value field **1126**. Although the illustrated fields **1122**, **1124**, and **1126** are illustrated as approximately equivalent in size, the size of each field may be variable and vary in size in relation to each other. In other embodiments, the TLV packet **1120** may further include a control byte before the tag field **1122**.

In embodiments having the control byte, the control byte may be sub-divided into an element type field and a tag control field. In some embodiments, the element type field includes 5 lower bits of the control byte and the tag control field occupies the upper 3 bits. The element type field indicates the TLV element's type as well as the how the length field **1124** and value field **1126** are encoded. In certain embodiments, the element type field also encodes Boolean values and/or null values for the TLV. For example, an embodiment of an enumeration of element type field is provided in Table 1 below.

TABLE 1

Example element type field values.

7	6	5	4	3	2	1	0	
			0	0	0	0	0	Signed Integer, 1 byte value
			0	0	0	0	1	Signed Integer, 2 byte value
			0	0	0	1	0	Signed Integer, 4 byte value
			0	0	0	1	1	Signed Integer, 8 byte value
			0	0	1	0	0	Unsigned Integer, 1 byte value
			0	0	1	0	1	Unsigned Integer, 2 byte value
			0	0	1	1	0	Unsigned Integer, 4 byte value
			0	0	1	1	1	Unsigned Integer, 8 byte value
			0	1	0	0	0	Boolean False
			0	1	0	0	1	Boolean True
			0	1	0	1	0	Floating Point Number, 4 byte value
			0	1	0	1	1	Floating Point Number, 8 byte value
			0	1	1	0	0	UTF8-String, 1 byte length
			0	1	1	0	1	UTF8-String, 2 byte length
			0	1	1	1	0	UTF8-String, 4 byte length
			0	1	1	1	1	UTF8-String, 8 byte length
			1	0	0	0	0	Byte String, 1 byte length
			1	0	0	0	1	Byte String, 2 byte length
			1	0	0	1	0	Byte String, 4 byte length
			1	0	0	1	1	Byte String, 8 byte length
			1	0	1	0	0	Null
			1	0	1	0	1	Dictionary
			1	0	1	1	0	Array
			1	0	1	1	1	Path
			1	1	0	0	0	End of Container

The tag control field indicates a form of the tag in the tag field **1122** assigned to the TLV element (including a zero-length tag). Examples, of tag control field values are provided in Table 2 below.

TABLE 2

Example values for tag control field.

7	6	5	4	3	2	1	0	
0	0	0						Anonymous, 0 bytes
0	0	1						Context-specific Tag, 1 byte
0	1	0						Core Profile Tag, 2 bytes
0	1	1						Core Profile Tag, 4 bytes
1	0	0						Implicit Profile Tag, 2 bytes
1	0	1						Implicit Profile Tag, 4 bytes
1	1	0						Fully-qualified Tag, 6 bytes
1	1	1						Fully-qualified Tag, 8 bytes

In other words, in embodiments having a control byte, the control byte may indicate a length of the tag.

In certain embodiments, the tag field **1122** may include zero to eight bytes, such as eight, sixteen, thirty two, or sixty four bits. In some embodiments, the tag of the tag field may be classified as profile-specific tags or context-specific tags. Profile-specific tags identify elements globally using a vendor Id, a profile Id, and/or tag number as discussed below. Context-specific tags identify TLV elements within a context

of a containing dictionary element and may include a single-byte tag number. Since context-specific tags are defined in context of their containers, a single context-specific tag may have different interpretations when included in different containers. In some embodiments, the context may also be derived from nested containers.

In embodiments having the control byte, the tag length is encoded in the tag control field and the tag field **1122** includes a possible three fields: a vendor Id field, a profile Id field, and a tag number field. In the fully-qualified form, the encoded tag field **1122** includes all three fields with the tag number field including 16 or 32 bits determined by the tag control field. In the implicit form, the tag includes only the tag number, and the vendor Id and profile number are inferred from the protocol context of the TLV element. The core profile form includes profile-specific tags, as discussed above. Context-specific tags are encoded as a single byte conveying the tag number. Anonymous elements have zero-length tag fields **1122**.

In some embodiments without a control byte, two bits may indicate a length of the tag field **1122**, two bits may indicate a length of the length field **1124**, and four bits may indicate a type of information stored in the value field **1126**. An example of possible encoding for the upper 8 bits for the tag field is illustrated below in Table 3.

TABLE 3

Tag field of a TLV packet

Byte 0 7	6	5	4	3	2	1	0	Description
0	0	—	—	—	—	—	—	Tag is 8 bits
0	1	—	—	—	—	—	—	Tag is 16 bits
1	0	—	—	—	—	—	—	Tag is 32 bits
1	1	—	—	—	—	—	—	Tag is 64 bits
—	—	0	0	—	—	—	—	Length is 8 bits
—	—	0	1	—	—	—	—	Length is 16 bits
—	—	1	0	—	—	—	—	Length is 32 bits
—	—	1	1	—	—	—	—	Length is 64 bits
—	—			0	0	0	0	Boolean
—	—			0	0	0	1	Fixed 8-bit Unsigned
—	—			0	0	1	0	Fixed 8-bit Signed
—	—			0	0	1	1	Fixed 16-bit Unsigned
—	—			0	1	0	0	Fixed 16-bit Signed
—	—			0	1	0	1	Fixed 32-bit Unsigned
—	—			0	1	1	0	Fixed 32-bit Signed
—	—			0	1	1	1	Fixed 64-bit Unsigned
—	—			1	0	0	0	Fixed 64-bit Signed
—	—			1	0	0	1	32-bit Floating Point
—	—			1	0	1	0	64-bit Floating Point
—	—			1	0	1	1	UTF-8 String
—	—			1	1	0	0	Opaque Data
—	—			1	1	0	1	Container

As illustrated in Table 3, the upper 8 bits of the tag field **1122** may be used to encode information about the tag field **1122**, length field **1124**, and the value field **1126**, such that the tag field **112** may be used to determine length for the tag field **122** and the length fields **1124**. Remaining bits in the tag field **1122** may be made available for user-allocated and/or user-assigned tag values.

The length field **1124** may include eight, sixteen, thirty two, or sixty four bits as indicated by the tag field **1122** as illustrated in Table 3 or the element field as illustrated in Table 2. Moreover, the length field **1124** may include an unsigned integer that represents a length of the encoded in the value field **1126**. In some embodiments, the length may be selected by a device sending the TLV element. The value field **1126** includes the payload data to be decoded, but interpretation of the value field **1126** may depend upon the tag length fields, and/or control byte. For example, a TLV packet without a control byte including an 8 bit tag is illustrated in Table 4 below for illustration.

TABLE 4

Example of a TLV packet including an 8-bit tag

Tag	Length	Value	Description
0x0d	0x24		
0x09	0x04	0x42 95 00 00	74.5
0x09	0x04	0x42 98 66 66	76.2
0x09	0x04	0x42 94 99 9a	74.3
0x09	0x04	0x42 98 99 9a	76.3
0x09	0x04	0x42 95 33 33	74.6
0x09	0x04	0x42 98 33 33	76.1

As illustrated in Table 4, the first line indicates that the tag field **1122** and the length field **1124** each have a length of 8 bits. Additionally, the tag field **1122** indicates that the tag type is for the first line is a container (e.g., the TLV packet). The tag field **1124** for lines two through six indicate that each entry in the TLV packet has a tag field **1122** and length field **1124** consisting of 8 bits each. Additionally, the tag field **1124** indicates that each entry in the TLV packet has a value field **1126** that includes a 32-bit floating point. Each entry in the value field **1126** corresponds to a floating number that may be decoded using the corresponding tag field **1122** and length field **1124** information. As illustrated in this example, each entry in the value field **1126** corresponds to a temperature in Fahrenheit. As can be understood, by storing data in a TLV packet as described above, data may be transferred compactly while remaining flexible for varying lengths and information as may be used by different devices in the fabric. Moreover, in some embodiments, multi-byte integer fields may be transmitted in little-endian order or big-endian order.

By transmitting TLV packets in using an order protocol (e.g., little-endian) that may be used by sending/receiving device formats (e.g., JSON), data transferred between nodes may be transmitted in the order protocol used by at least one of the nodes (e.g., little endian). For example, if one or more nodes include ARM or ix86 processors, transmissions between the nodes may be transmitted using little-endian byte ordering to reduce the use of byte reordering. By reducing the inclusion of byte reordering, the TLV format enable devices to communicate using less power than a transmission that uses byte reordering on both ends of the transmission. Furthermore, TLV formatting may be specified to provide a one-to-one translation between other data storage techniques, such as JSON+ Extensible Markup Language (XML). As an example, the TLV format may be used to represent the following XML Property List:


```
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE plist PUBLIC "-//Apple Computer//DTD PLIST 1.0//EN"
"http://www.apple.com/DTDs/PropertyList-1.0.dtd">
<plist version="1.0">
<dict>
  <key>OfflineMode</key>
  <false/>
  <key>Network</key>
  <dict>
    <key>IPv4</key>
    <dict>
      <key>Method</key>
      <string>dhcp</string>
```

-continued

```
    </dict>
    <key>IPv6</key>
    <dict>
      <key>Method</key>
      <string>auto</string>
    </dict>
  </dict>
  <key>Technologies</key>
  <dict>
    <key>wifi</key>
    <dict>
      <key>Enabled</key>
      <true/>
      <key>Devices</key>
      <dict>
        <key>wifi_18b4300008b027</key>
        <dict>
        <key>Enabled</key>
        <true/>
      </dict>
     </dict>
     <key>Services</key>
     <array>
        <string>wifi_18b4300008b027_3939382d33204 16
      c70696e652054657 272616365</string>
     </array>
    </dict>
    <key>802.15.4</key>
    <dict>
     <key>Enabled</key>
     <true/>
     <key>Devices</key>
     <dict>
      <key>802.15.4_18b43000000002fac4</key>
      <dict>
        <key>Enabled</key>
        <true/>
      </dict>
     </dict>
     <key>Services</key>
     <array>
      <string>802.15.4_18b43000000002fac4_3 939382d332041
      6c70696e6520546572</string>
     </array>
   </dict>
  </dict>
  <key>Services</key>
  <dict>
  <key>wifi_18b4300008b027_3939382d3320416c70696e6520546572
  72616365</key>
    <dict>
     <key>Name</key>
     <string>998-3 Alpine Terrace</string>
     <key>SSID</key>
     <data>3939382d3320416c70696e652054657272616365
     </data>
     <key>Frequency</key>
     <integer>2462</integer>
     <key>AutoConnect</key>
     <true/>
     <key>Favorite</key>
     <true/>
     <key>Error</key>
     <string/>
     <key>Network</key>
     <dict>
      <key>IPv4</key>
      <dict>
        <key>DHCP</key>
        <dict>
          <key>LastAddress</key>
          <data>0a02001e</data>
        </dict>
      </dict>
      <key>IPv6</key>
      <dict/>
     </dict>
    </dict>
    <key>802.15.4_18b43000000002fac4_3939382d3320416c70696e
```

-continued

```
    6520546572</key>
    <dict>
      <key>Name</key>
      <string>998-3 Alpine Ter</string>
      <key>EPANID</key>
      <data>3939382d3320416c70696e6520546572</data>
      <key>Frequency</key>
      <integer>2412</integer>
      <key>AutoConnect</key>
      <true/>
      <key>Favorite</key>
      <true/>
      <key>Error</key>
      <string/>
      <key>Network</key>
      <dict/>
    </dict>
  </dict>
</dict>
</plist
```

As an example, the above property list may be represented in tags of the above described TLV format (without a control byte) according to Table 5 below.

TABLE 5

Example representation of the XML Property List in TLV format

XML Key	Tag Type	Tag Number
OfflineMode	Boolean	1
IPv4	Container	3
IPv6	Container	4
Method	String	5
Technologies	Container	6
WiFi	Container	7
802.15.4	Container	8
Enabled	Boolean	9
Devices	Container	10
ID	String	11
Services	Container	12
Name	String	13
SSID	Data	14
EPANID	Data	15
Frequency	16-bit Unsigned	16
AutoConnect	Boolean	17
Favorite	Boolean	18
Error	String	19
DHCP	String	20
LastAddress	Data	21
Device	Container	22
Service	Container	23

Similarly, Table 6 illustrates an example of literal tag, length, and value representations for the example XML Property List.

TABLE 6

Example of literal values for tag, length, and value fields for XML Property List

Tag	Length	Value	Description
0x40 01	0x01	0	OfflineMode
0x4d 02	0x14		Network
0x4d 03	0x07		Network.IPv4
0x4b 05	0x04	“dhcp”	Network.IPv4.Method
0x4d 04	0x07		Network.IPv6
0x4b 05	0x04	“auto”	Network.IPv6.Method
0x4d 06	0xd6		Technologies
0x4d 07	0x65		Technologies.wifi
0x40 09	0x01	1	Technologies.wifi.Enabled
0x4d 0a	0x5e		Technologies.wifi.Devices
0x4d 16	0x5b		Technologies.wifi.Devices.Device.[0]
0x4b 0b	0x13	“wifi_18b43 . . . ”	Technologies.wifi.Devices.Device.[0].ID
0x40 09	0x01	1	Technologies.wifi.Devices.Device.[0].Enabled
0x4d 0c	0x3e		Technologies.wifi.Devices.Device.[0].Services
0x0b	0x3c	“wifi_18b43 . . . ”	Technologies.wifi.Devices.Device.[0].Services.[0]
0x4d 08	0x6b		Technologies.802.15.4
0x40 09	0x01	1	Technologies.802.15.4.Enabled
0x4d 0a	0x64		Technologies.802.15.4.Devices
0x4d 16	0x61		Technologies.802.15.4.Devices.Device.[0]
0x4b 0b	0x1a	“802.15.4_18 . . . ”	Technologies.802.15.4.Devices.Device.[0].ID
0x40 09	0x01	1	Technologies.802.15.4.Devices.Device.[0].Enabled
0x4d 0c	0x3d		Technologies.802.15.4.Devices.Device.[0].Services
0x0b	0x3b	“802.15.4_18 . . . ”	Technologies.802.15.4.Devices.Device.[0].Services.[0]
0x4d 0c	0xcb		Services
0x4d 17	0x75		Services.Service.[0]
0x4b 0b	0x13	“wifi_18b43 . . . ”	Services.Service.[0].ID
0x4b 0d	0x14	“998-3 Alp . . . ”	Services.Service.[0].Name
0x4c 0f	0x28	3939382d . . .	Services.Service.[0].SSID
0x45 10	0x02	2462	Services.Service.[0].Frequency
0x40 11	0x01	1	Services.Service.[0].AutoConnect
0x40 12	0x01	1	Services.Service.[0].Favorite
0x4d 02	0x0d		Services.Service.[0].Network
0x4d 03	0x0a		Services.Service.[0].Network.IPv4
0x4d 14	0x07		Services.Service.[0].Network.IPv4.DHCP
0x45 15	0x04	0x0a02001e	Services.Service.[0].Network.IPv4.LastAddress
0x4d 17	0x50		Services.Service.[1]
0x4b 0b	0x1a	“802.15.4_18 . . . ”	Services.Service.[1].ID
0x4c 0d	0x10	“998-3 Alp . . . ”	Services.Service.[1].Name
0x4c 0f	0x10	3939382d . . .	Services.Service.[1].EPANID

TABLE 6-continued

Example of literal values for tag, length, and value fields for XML Property List			
Tag	Length	Value	Description
0x45 10	0x02	2412	Services.Service.[1].Frequency
0x40 11	0x01	1	Services.Service.[1].AutoConnect
0x40 12	0x01	1	Services.Service.[1].Favorite

The TLV format enables reference of properties that may also be enumerated with XML, but does so with a smaller storage size. For example, Table 7 illustrates a comparison of data sizes of the XML Property List, a corresponding binary property list, and the TLV format.

TABLE 7

Comparison of the sizes of property list data sizes.		
List Type	Size in Bytes	Percentage of XML Size
XML	2,199	—
Binary	730	−66.8%
TLV	450	−79.5%

By reducing the amount of data used to transfer data, the TLV format enables the fabric **1000** transfer data to and/or from devices having short duty cycles due to limited power (e.g., battery supplied devices). In other words, the TLV format allows flexibility of transmission while increasing compactness of the data to be transmitted.

C. General Message Protocol

In addition to sending particular entries of varying sizes, data may be transmitted within the fabric using a general message protocol that may incorporate TLV formatting. An embodiment of a general message protocol (GMP) **1128** is illustrated in FIG. **12**. In certain embodiments, the general message protocol (GMP) **1128** may be used to transmit data within the fabric. The GMP **1128** may be used to transmit data via connectionless protocols (e.g., UDP) and/or connection-oriented protocols (e.g., TCP). Accordingly, the GMP **1128** may flexibly accommodate information that is used in one protocol while ignoring such information when using another protocol. Moreover, the GMP **1226** may enable omission of fields that are not used in a specific transmission. Data that may be omitted from one or more GMP **1226** transfers is generally indicated using grey borders around the data units. In some embodiments, the multi-byte integer fields may be transmitted in a little-endian order or a big-endian order.

i. Packet Length

In some embodiments, the GMP **1128** may include a Packet Length field **1130**. In some embodiments, the Packet Length field **1130** includes 2 bytes. A value in the Packet Length field **1130** corresponds to an unsigned integer indicating an overall length of the message in bytes, excluding the Packet Length field **1130** itself. The Packet Length field **1130** may be present when the GMP **1128** is transmitted over a TCP connection, but when the GMP **1128** is transmitted over a UDP connection, the message length may be equal to the payload length of the underlying UDP packet obviating the Packet Length field **1130**.

ii. Message Header

The GMP **1128** may also include a Message Header **1132** regardless of whether the GMP **1128** is transmitted using TCP or UDP connections. In some embodiments, the Message Header **1132** includes two bytes of data arranged in the format illustrated in FIG. **13**. As illustrated in FIG. **13**, the Message Header **1132** includes a Version field **1156**. The Version field **1156** corresponds to a version of the GMP **1128** that is used to encode the message. Accordingly, as the GMP **1128** is updated, new versions of the GMP **1128** may be created, but each device in a fabric may be able to receive a data packet in any version of GMP **1128** known to the device. In addition to the Version field **1156**, the Message Header **1132** may include an S Flag field **1158** and a D Flag **1160**. The S Flag **1158** is a single bit that indicates whether a Source Node Id (discussed below) field is included in the transmitted packet. Similarly, the D Flag **1160** is a single bit that indicates whether a Destination Node Id (discussed below) field is included in the transmitted packet.

The Message Header **1132** also includes an Encryption Type field **1162**. The Encryption Type field **1162** includes four bits that specify which type of encryption/integrity checking applied to the message, if any. For example, 0x0 may indicate that no encryption or message integrity checking is included, but a decimal 0x1 may indicate that AES-128-CTR encryption with HMAC-SHA-1 message integrity checking is included.

Finally, the Message Header **1132** further includes a Signature Type field **1164**. The Signature Type field **1164** includes four bits that specify which type of digital signature is applied to the message, if any. For example, 0x0 may indicate that no digital signature is included in the message, but 0x1 may indicate that the Elliptical Curve Digital Signature Algorithm (ECDSA) with Prime256v1 elliptical curve parameters is included in the message.

iii. Message Id

Returning to FIG. **12**, the GMP **1128** also includes a Message Id field **1134** that may be included in a transmitted message regardless of whether the message is sent using TCP or UDP. The Message Id field **1134** includes four bytes that correspond to an unsigned integer value that uniquely identifies the message from the perspective of the sending node. In some embodiments, nodes may assign increasing Message Id **1134** values to each message that they send returning to zero after reaching 2^{32} messages.

iv. Source Node Id

In certain embodiments, the GMP **1128** may also include a Source Node Id field **1136** that includes eight bytes. As discussed above, the Source Node Id field **1136** may be present in a message when the single-bit S Flag **1158** in the Message Header **1132** is set to 1. In some embodiments, the Source Node Id field **1136** may contain the Interface ID **1104** of the ULA **1098** or the entire ULA **1098**. In some embodiments, the bytes of the Source Node Id field **1136** are transmitted in an ascending index-value order (e.g., EUI[0] then EUI[1] then EUI[2] then EUI[3], etc.).

v. Destination Node Id

The GMP **1128** may include a Destination Node Id field **1138** that includes eight bytes. The Destination Node Id field **1138** is similar to the Source Node Id field **1136**, but the Destination Node Id field **1138** corresponds to a destination node for the message. The Destination Node Id field **1138** may be present in a message when the single-bit D Flag **1160** in the Message Header **1132** is set to 1. Also similar to the Source Node Id field **1136**, in some embodiments, bytes of the Destination Node Id field **1138** may be transmitted in an ascending index-value order (e.g., EUI[0] then EUI[1] then EUI[2] then EUI[3], etc.).

vi. Key Id

In some embodiments, the GMP **1128** may include a Key Id field **1140**. In certain embodiments, the Key Id field **1140** includes two bytes. The Key Id field **1140** includes an unsigned integer value that identifies the encryption/message integrity keys used to encrypt the message. The presence of the Key Id field **1140** may be determined by the value of Encryption Type field **1162** of the Message Header **1132**. For example, in some embodiments, when the value for the Encryption Type field **1162** of the Message Header **1132** is 0x0, the Key Id field **1140** may be omitted from the message.

An embodiment of the Key Id field **1140** is presented in FIG. **14**. In the illustrated embodiment, the Key Id field **1140** includes a Key Type field **1166** and a Key Number field **1168**. In some embodiments, the Key Type field **1166** includes four bits. The Key Type field **1166** corresponds to an unsigned integer value that identifies a type of encryption/message integrity used to encrypt the message. For example, in some embodiments, if the Key Type field **1166** is 0x0, the fabric key is shared by all or most of the nodes in the fabric. However, if the Key Type field **1166** is 0x1, the fabric key is shared by a pair of nodes in the fabric.

The Key Id field **1140** also includes a Key Number field **1168** that includes twelve bits that correspond to an unsigned integer value that identifies a particular key used to encrypt the message out of a set of available keys, either shared or fabric keys.

vii. Payload Length

In some embodiments, the GMP **1128** may include a Payload Length field **1142**. The Payload Length field **1142**, when present, may include two bytes. The Payload Length field **1142** corresponds to an unsigned integer value that indicates a size in bytes of the Application Payload field. The Payload Length field **1142** may be present when the message is encrypted using an algorithm that uses message padding, as described below in relation to the Padding field.

viii. Initialization Vector

In some embodiments, the GMP **1128** may also include an Initialization Vector (IV) field **1144**. The IV field **1144**, when present, includes a variable number of bytes of data. The IV field **1144** contains cryptographic IV values used to encrypt the message. The IV field **1144** may be used when the message is encrypted with an algorithm that uses an IV. The length of the IV field **1144** may be derived by the type of encryption used to encrypt the message.

ix. Application Payload

The GMP **1128** includes an Application Payload field **1146**. The Application Payload field **1146** includes a variable number of bytes. The Application Payload field **1146** includes application data conveyed in the message. The length of the Application Payload field **1146** may be determined from the Payload Length field **1142**, when present. If the Payload Length field **1142** is not present, the length of the Application Payload field **1146** may be determined by subtracting the length of all other fields from the overall length of the message and/or data values included within the Application Payload **1146** (e.g., TLV).

An embodiment of the Application Payload field **1146** is illustrated in FIG. **15**. The Application Payload field **1146** includes an APVersion field **1170**. In some embodiments, the APVersion field **1170** includes eight bits that indicate what version of fabric software is supported by the sending device. The Application Payload field **1146** also includes a Message Type field **1172**. The Message Type field **1172** may include eight bits that correspond to a message operation code that indicates the type of message being sent within a profile. For example, in a software update profile, a 0x00 may indicate that the message being sent is an image announce. The Application Payload field **1146** further includes an Exchange Id field **1174** that includes sixteen bits that corresponds to an exchange identifier that is unique to the sending node for the transaction.

In addition, the Application Payload field **1146** includes a Profile Id field **1176**. The Profile Id **1176** indicates a "theme of discussion" used to indicate what type of communication occurs in the message. The Profile Id **1176** may correspond to one or more profiles that a device may be capable of communicating. For example, the Profile Id **1176** may indicate that the message relates to a core profile, a software update profile, a status update profile, a data management profile, a climate and comfort profile, a security profile, a safety profile, and/or other suitable profile types. Each device on the fabric may include a list of profiles which are relevant to the device and in which the device is capable of "participating in the discussion." For example, many devices in a fabric may include the core profile, the software update profile, the status update profile, and the data management profile, but only some devices would include the climate and comfort profile. The APVersion field **1170**, Message Type field **1172**, the Exchange Id field, the Profile Id field **1176**, and the Profile-Specific Header field **1176**, if present, may be referred to in combination as the "Application Header."

In some embodiments, an indication of the Profile Id via the Profile Id field **1176** may provide sufficient information to provide a schema for data transmitted for the profile. However, in some embodiments, additional information may be used to determine further guidance for decoding the Application Payload field **1146**. In such embodiments, the Application Payload field **1146** may include a Profile-Specific Header field **1178**. Some profiles may not use the Profile-Specific Header field **1178** thereby enabling the Application Payload field **1146** to omit the Profile-Specific Header field **1178**. Upon determination of a schema from the Profile Id field **1176** and/or the Profile-Specific Header field **1178**, data may be encoded/decoded in the Application Payload sub-field **1180**. The Application Payload sub-field **1180** includes the core application data to be transmitted between devices and/or services to be stored, rebroadcast, and/or acted upon by the receiving device/service.

x. Message Integrity Check

Returning to FIG. **12**, in some embodiments, the GMP **1128** may also include a Message Integrity Check (MIC) field **1148**. The MIC field **1148**, when present, includes a variable length of bytes of data containing a MIC for the message. The length and byte order of the field depends upon the integrity check algorithm in use. For example, if the message is checked for message integrity using HMAC-SHA-1, the MIC field **1148** includes twenty bytes in big-endian order. Furthermore, the presence of the MIC field **1148** may be determined by whether the Encryption Type field **1162** of the Message Header **1132** includes any value other than 0x0.

xi. Padding

The GMP **1128** may also include a Padding field **1150**. The Padding field **1150**, when present, includes a sequence of bytes representing a cryptographic padding added to the message to make the encrypted portion of the message evenly divisible by the encryption block size. The presence of the Padding field **1150** may be determined by whether the type of encryption algorithm (e.g., block ciphers in cipher-block chaining mode) indicated by the Encryption Type field **1162** in the Message Header **1132** uses cryptographic padding.

xii. Encryption

The Application Payload field **1146**, the MIC field **1148**, and the Padding field **1150** together form an Encryption block **1152**. The Encryption block **1152** includes the portions of the message that are encrypted when the Encryption Type field **1162** in the Message Header **1132** is any value other than 0x0.

xiii. Message Signature

The GMP **1128** may also include a Message Signature field **1154**. The Message Signature field **1154**, when present, includes a sequence of bytes of variable length that contains a cryptographic signature of the message. The length and the contents of the Message Signature field may be determined according to the type of signature algorithm in use and indicated by the Signature Type field **1164** of the Message Header **1132**. For example, if ECDSA using the Prime256v1 elliptical curve parameters is the algorithm in use, the Message Signature field **1154** may include two thirty-two bit integers encoded in little-endian order.

IV. Profiles and Protocols

As discussed above, one or more schemas of information may be selected upon desired general discussion type for the message. A profile may consist of one or more schemas. For example, one set of schemas of information may be used to encode/decode data in the Application Payload sub-field **1180** when one profile is indicated in the Profile Id field **1176** of the Application Payload **1146**. However, a different set of schemas may be used to encode/decode data in the Application Payload sub-field **1180** when a different profile is indicated in the Profile Id field **1176** of the Application Payload **1146**.

FIG. **16** illustrates a schematic view of a variety of profiles that may be used in various messages. For example, one or more profile schemas may be stored in a profile library **300** that may be used by the devices to encode or decode messages based on a profile ID. The profile library **300** may organize the profiles into groups. For example, an application- and vendor-specific profile group **302** of profiles may be application- and vendor-specific profiles, and a provisioning group **304** of profiles may profiles used to provision networks, services, and/or fabrics. The application- and vendor-specific profile group **302** may include a software update profile **306**, a locale profile **308**, a time profile **310**, a sensor profile **312**, an access control profile **314**, an alarm profile **316**, and one or more vendor unique profiles **318**. The software update profile **306** may be used by the devices to update software within the devices. The locale profile **308** may be used to specify a location and/or language set as the active locale for the device. The alarm profile **316** may be used to send, read, and propagate alarms.

The profiles library **300** may also include a device control profile **320**, a network provisioning profile **322**, a fabric provisioning profile **324**, and a service provisioning profile **326**. The device control profile **320** allows one device to request that another device exercise a specified device control (e.g., arm failsafe, etc.) capability. The network provisioning profile **322** enables a device to be added to a new logical network (e.g., WiFi or 802.15.4). The fabric provisioning profile **324** allows the devices to join a pre-existing fabric or create a new fabric. The service provisioning profile **326** enables the devices to be paired to a service.

The profiles library **300** may also include a strings profile **328**, a device description profile **330**, a device profile **332**, device power extended profile **334**, a device power profile **336**, a device connectivity extended profile **338**, a device connectivity profile **340**, a service directory profile **342**, a data management profile **344**, an echo profile **346**, a security profile **348**, and a core profile **350**. The device description profile **330** may be used by a device to identify one or more other devices. The service directory profile **342** enables a device to communicate with a service. The data management profile **344** enables devices to view and/or track data stored in another device. The echo profile **346** enables a device to determine whether the device is connected to a target device and the latency in the connection. The security profile **348** enables the devices to communicate securely.

The core profile **350** includes a status reporting profile **352** that enables devices to report successes and failures of requested actions. Additionally, in certain embodiments, each device may include a set of methods used to process profiles. For example, a core protocol may include the following profiles: GetProfiles, GetSchema, GetSchemas, GetProperty, GetProperties, SetProperty, SetProperties, RemoveProperty, RemoveProperties, RequestEcho, NotifyPropertyChanged, and/or NotifyPropertiesChanged. The Get Profiles method may return an array of profiles supported by a queried node. The GetSchema and GetSchemas methods may respectively return one or all schemas for a specific profile. GetProperty and GetProperties may respectively return a value or all value pairs for a profile schema. SetProperty and SetProperties may respectively set single or multiple values for a profile schema. RemoveProperty and RemoveProperties may respectively attempt to remove a single or multiple values from a profile schema. RequestEcho may send an arbitrary data payload to a specified node which the node returns unmodified. NotifyPropertyChange and NotifyPropertiesChanged may respectively issue a notification if a single/multiple value pairs have changed for a profile schema.

To aid in understanding profiles and schemas, a non-exclusive list of profiles and schemas are provided below for illustrative purposes.

A. Status Reporting

A status reporting schema is presented as the status reporting frame **1182** in FIG. **17**. The status reporting schema may be a separate profile or may be included in one or more profiles (e.g., a core profile). In certain embodiments, the status reporting frame **1182** includes a profile field **1184**, a status code field **1186**, a next status field **1188**, and may include an additional status info field **1190**.

i. Profile Field

In some embodiments, the profile field **1184** includes four bytes of data that defines the profile under which the information in the present status report is to be interpreted. An embodiment of the profile field **1184** is illustrated in FIG. **18** with two sub-fields. In the illustrated embodiment, the profile field **1184** includes a profile Id sub-field **1192** that includes sixteen bits that corresponds to a vendor-specific identifier for the profile under which the value of the status code field **1186** is defined. The profile field **1184** may also includes a vendor Id sub-field **1194** that includes sixteen bits that identifies a vendor providing the profile identified in the profile Id sub-field **1192**.

ii. Status Code

In certain embodiments, the status code field **1186** includes sixteen bits that encode the status that is being reported. The values in the status code field **1186** are interpreted in relation to values encoded in the vendor Id sub-field **1192** and the profile Id sub-field **1194** provided in the profile field **1184**. Additionally, in some embodiments, the status code space may be divided into four groups, as indicated in Table 8 below.

TABLE 8

Status Code Range Table

Range	Name	Description
0x0000 . . . 0x0010	success	A request was successfully processed.
0x0011 . . . 0x0020	client error	An error has or may have occurred on the client-side of a client/server exchange. For example, the client has made a badly-formed request.
0x0021 . . . 0x0030	server error	An error has or may have occurred on the server side of a client/server exchange. For example, the server has failed to process a client request to an operating system error.
0x0031 . . . 0x0040	continue/ redirect	Additional processing will be used, such as redirection, to complete a particular exchange, but no errors yet.

Although Table 8 identifies general status code ranges that may be used separately assigned and used for each specific profile Id, in some embodiments, some status codes may be common to each of the profiles. For example, these profiles may be identified using a common profile (e.g., core profile) identifier, such as 0x00000000.

iii. Next Status

In some embodiments, the next status code field **1188** includes eight bits. The next status code field **1188** indicates whether there is following status information after the currently reported status. If following status information is to be included, the next status code field **1188** indicates what type of status information is to be included. In some embodiments, the next status code field **1188** may always be included, thereby potentially increasing the size of the message. However, by providing an opportunity to chain status information together, the potential for overall reduction of data sent may be reduced. If the next status field **1186** is 0x00, no following status information field **1190** is included. However, non-zero values may indicate that data may be included and indicate the form in which the data is included (e.g., in a TLV packet).

iv. Additional Status Info

When the next status code field **1188** is non-zero, the additional status info field **1190** is included in the message. If present, the status item field may contain status in a form that may be determined by the value of the preceding status type field (e.g., TLV format)

B. Software Update

The software update profile or protocol is a set of schemas and a client/server protocol that enables clients to be made aware of or seek information about the presence of software that they may download and install. Using the software update protocol, a software image may be provided to the profile client in a format known to the client. The subsequent processing of the software image may be generic, device-specific, or vendor-specific and determined by the software update protocol and the devices.

i. General Application Headers for the Application Payload

In order to be recognized and handled properly, software update profile frames may be identified within the Application Payload field **1146** of the GMP **1128**. In some embodiments, all software update profile frames may use a common Profile Id **1176**, such as 0x0000000C. Additionally, software update profile frames may include a Message Type field **1172** that indicates additional information and may chosen according to Table 9 below and the type of message being sent.

TABLE 9

Software update profile message types

Type	Message
0x00	image announce
0x01	image query
0x02	image query response
0x03	download notify
0x04	notify response
0x05	update notify
0x06 . . . 0xff	reserved

Additionally, as described below, the software update sequence may be initiated by a server sending the update as an image announce or a client receiving the update as an image query. In either embodiment, an Exchange Id **1174** from the initiating event is used for all messages used in relation to the software update.

ii. Protocol Sequence

FIG. **19** illustrates an embodiment of a protocol sequence **1196** for a software update between a software update client **1198** and a software update server **1200**. In certain embodiments, any device in the fabric may be the software update client **1198** or the software update server **1200**. Certain embodiments of the protocol sequence **1196** may include additional steps, such as those illustrated as dashed lines that may be omitted in some software update transmissions.

1. Service Discovery

In some embodiments, the protocol sequence **1196** begins with a software update profile server announcing a presence of the update. However, in other embodiments, such as the illustrated embodiment, the protocol sequence **1196** begins with a service discovery **1202**, as discussed above.

2. Image Announce

In some embodiments, an image announce message **1204** may be multicast or unicast by the software update server **1200**. The image announce message **1204** informs devices in the fabric that the server **1200** has a software update to offer. If the update is applicable to the client **1198**, upon receipt of the image announce message **1204**, the software update client **1198** responds with an image query message **1206**. In certain embodiments, the image announce message **1204** may not be included in the protocol sequence **1196**. Instead, in such embodiments, the software update client **1198** may use a polling schedule to determine when to send the image query message **1206**.

3. Image Query

In certain embodiments, the image query message **1206** may be unicast from the software update client **1198** either in response to an image announce message **1204** or according to a polling schedule, as discussed above. The image query message **1206** includes information from the client **1198** about itself. An embodiment of a frame of the image query message **1206** is illustrated in FIG. **20**. As illustrated in FIG. **20**, certain embodiments of the image query message **1206** may include a frame control field **1218**, a product specification field **1220**, a vendor specific data field **1222**, a version specification field **1224**, a locale specification field **1226**, an integrity type supported field **1228**, and an update schemes supported field **1230**.

a. Frame Control

The frame control field **1218** includes 1 byte and indicates various information about the image query message **1204**. An example of the frame control field **128** is illustrated in FIG. **21**. As illustrated, the frame control field **1218** may include three sub-fields: vendor specific flag **1232**, locale specification flag **1234**, and a reserved field S3. The vendor specific flag **1232** indicates whether the vendor specific data field **1222** is included in the message image query message. For example, when the vendor specific flag **1232** is 0 no vendor specific data field **1222** may be present in the image query message, but when the vendor specific flag **1232** is 1 the vendor specific data field **1222** may be present in the image query message. Similarly, a 1 value in the locale specification flag **1234** indicates that a locale specification field **1226** is present in the image query message, and a 0 value indicates that the locale specification field **1226** in not present in the image query message.

b. Product Specification

The product specification field **1220** is a six byte field. An embodiment of the product specification field **1220** is illustrated in FIG. **22**. As illustrated, the product specification field **1220** may include three sub-fields: a vendor Id field **1236**, a product Id field **1238**, and a product revision field **1240**. The vendor Id field **1236** includes sixteen bits that indicate a vendor for the software update client **1198**. The product Id field **1238** includes sixteen bits that indicate the device product that is sending the image query message **1206** as the software update client **1198**. The product revision field **1240** includes sixteen bits that indicate a revision attribute of the software update client **1198**.

c. Vendor Specific Data

The vendor specific data field **1222**, when present in the image query message **1206**, has a length of a variable number of bytes. The presence of the vendor specific data field **1222** may be determined from the vendor specific flag **1232** of the frame control field **1218**. When present, the vendor specific data field **1222** encodes vendor specific information about the software update client **1198** in a TLV format, as described above.

d. Version Specification

An embodiment of the version specification field **1224** is illustrated in FIG. **23**. The version specification field **1224** includes a variable number of bytes sub-divided into two sub-fields: a version length field **1242** and a version string field **1244**. The version length field **1242** includes eight bits that indicate a length of the version string field **1244**. The version string field **1244** is variable in length and determined by the version length field **1242**. In some embodiments, the version string field **1244** may be capped at **255** UTF-8 characters in length. The value encoded in the version string field **1244** indicates a software version attribute for the software update client **1198**.

e. Locale Specification

In certain embodiments, the locale specification field **1226** may be included in the image query message **1206** when the locale specification flag **1234** of the frame control **1218** is 1. An embodiment of the locale specification field **1226** is illustrated in FIG. **24**. The illustrated embodiment of the locale specification field **1226** includes a variable number of bytes divided into two sub-fields: a locale string length field **1246** and a locale string field **1248**. The locale string length field **1246** includes eight bits that indicate a length of the locale string field **1248**. The locale string field **1248** of the locale specification field **1226** may be variable in length and contain a string of UTF-8 characters encoding a local description based on Portable Operating System Interface (POSIX) locale codes. The standard format for POSIX locale codes is [language[_territory][.codeset][@modifier]] For example, the POSIX representation for Australian English is en_AU.UTF8.

f. Integrity Types Supported

An embodiment of the integrity types field **1228** is illustrated in FIG. **25**. The integrity types supported field **1228** includes two to four bytes of data divided into two sub-fields: a type list length field **1250** and an integrity type list field **1252**. The type list length field **1250** includes eight bits that indicate the length in bytes of the integrity type list field **1252**. The integrity type list field **1252** indicates the value of the software update integrity type attribute of the software update client **1198**. In some embodiments, the integrity type may be derived from Table 10 below.

TABLE 10

Example integrity types

Value	Integrity Type
0x00	SHA-160
0x01	SHA-256
0x02	SHA-512

The integrity type list field **1252** may contain at least one element from Table 10 or other additional values not included.

g. Update Schemes Supported

An embodiment of the schemes supported field **1230** is illustrated in FIG. **26**. The schemes supported field **1230** includes a variable number of bytes divided into two sub-fields: a scheme list length field **1254** and an update scheme list field **1256**. The scheme list length field **1254** includes eight bits that indicate a length of the update scheme list field in bytes. The update scheme list field **1256** of the update schemes supported field **1222** is variable in length determined by the scheme list length field **1254**. The update scheme list field **1256** represents an update schemes attributes of the software update profile of the software update client **1198**. An embodiment of example values is shown in Table 11 below.

TABLE 11

Example update schemes

Value	Update Scheme
0x00	HTTP
0x01	HTTPS
0x02	SFTP
0x03	Fabric-specific File Transfer Protocol (e.g., Bulk Data Transfer discussed below)

Upon receiving the image query message **1206**, the software update server **1200** uses the transmitted information to determine whether the software update server **1200** has an update for the software update client **1198** and how best to deliver the update to the software update client **1198**.

4. Image Query Response

Returning to FIG. **19**, after the software update server **1200** receives the image query message **1206** from the software update client **1198**, the software update server **1200** responds with an image query response **1208**. The image query response **1208** includes either information detailing why an update image is not available to the software update client **1198** or information about the available image update to enable to software update client **1198** to download and install the update.

An embodiment of a frame of the image query response **1208** is illustrated in FIG. **27**. As illustrated, the image query response **1208** includes five possible sub-fields: a query status field **1258**, a uniform resource identifier (URI) field **1260**, an integrity specification field **1262**, an update scheme field **1264**, and an update options field **1266**.

a. Query Status

The query status field **1258** includes a variable number of bytes and contains status reporting formatted data, as discussed above in reference to status reporting. For example, the query status field **1258** may include image query response status codes, such as those illustrated below in Table 12.

TABLE 12

Example image query response status codes

Profile	Code	Description
0x00000000	0x0000	The server has processed the image query message 1206 and has an update for the soft-ware update client 1198.
0x0000000C	0x0001	The server has processed the image query message 1206, but the server does not have an update for the software update client 1198.
0x00000000	0x0010	The server could not process the request because of improper form for the request.
0x00000000	0x0020	The server could not process the request due to an internal error

b. URI

The URI field **1260** includes a variable number of bytes. The presence of the URI field **1260** may be determined by the query status field **1258**. If the query status field **1258** indicates that an update is available, the URI field **1260** may be included. An embodiment of the URI field **1260** is illustrated in FIG. **28**. The URI field **1260** includes two sub-fields: a URI length field **1268** and a URI string field **1270**. The URI length field **1268** includes sixteen bits that indicates the length of the URI string field **1270** in UTF-8 characters. The URI string field **1270** and indicates the URI attribute of the software image update being presented, such that the software update client **1198** may be able to locate, download, and install a software image update, when present.

c. Integrity Specification

The integrity specification field **1262** may variable in length and present when the query status field **1258** indicates that an update is available from the software update server **1198** to the software update client **1198**. An embodiment of the integrity specification field **1262** is illustrated in FIG. **29**. As illustrated, the integrity specification field **1262** includes two sub-fields: an integrity type field **1272** and an integrity value field **1274**. The integrity type field **1272** includes eight bits that indicates an integrity type attribute for the software image update and may be populated using a list similar to that illustrated in Table 10 above. The integrity value field **1274** includes the integrity value that is used to verify that the image update message has maintained integrity during the transmission.

d. Update Scheme

The update scheme field **1264** includes eight bits and is present when the query status field **1258** indicates that an update is available from the software update server **1198** to the software update client **1198**. If present, the update scheme field **1264** indicates a scheme attribute for the software update image being presented to the software update server **1198**.

e. Update Options

The update options field **1266** includes eight bits and is present when the query status field **1258** indicates that an update is available from the software update server **1198** to the software update client **1198**. The update options field **1266** may be sub-divided as illustrated in FIG. **30**. As illustrated, the update options field **1266** includes four sub-fields: an update priority field **1276**, an update condition field **1278**, a report status flag **1280**, and a reserved field **1282**. In some embodiments, the update priority field **1276** includes two bits. The update priority field **1276** indicates a priority attribute of the update and may be determined using values such as those illustrated in Table 13 below.

TABLE 13

Example update priority values

Value	Description
00	Normal - update during a period of low network traffic
01	Critical - update as quickly as possible

The update condition field **1278** includes three bits that may be used to determine conditional factors to determine when or if to update. For example, values in the update condition field **1278** may be decoded using the Table 14 below.

TABLE 14

Example update conditions

Value	Decription
0	Update without conditions
1	Update if the version of the software running on the update client software does not match the update version.
2	Update if the version of the software running on the update client software is older than the update version.
3	Update if the user opts into an update with a user interface

The report status flag **1280** is a single bit that indicates whether the software update client **1198** should respond with a download notify message **1210**. If the report status flag **1280** is set to 1 the software update server **1198** is requesting a download notify message **1210** to be sent after the software update is downloaded by the software update client **1200**.

If the image query response **1208** indicates that an update is available. The software update client **1198** downloads **1210** the update using the information included in the image query response **1208** at a time indicated in the image query response **1208**.

5. Download Notify

After the update download **1210** is successfully completed or failed and the report status flag **1280** value is 1, the software update client **1198** may respond with the download notify message **1212**. The download notify message **1210** may be formatted in accordance with the status reporting format discussed above. An example of status codes used in the download notify message **1212** is illustrated in Table 15 below.

TABLE 15

Example download notify status codes		
Profile	Code	Description
0x00000000	0x0000	The download has been completed, and integrity verified
0x0000000C	0x0020	The download could not be completed due to faulty download instructions.
0x0000000C	0x0021	The image query response message 1208 appears proper, but the download or integrity verification failed.
0x0000000C	0x0022	The integrity of the download could not be verified.

In addition to the status reporting described above, the download notify message **1208** may include additional status information that may be relevant to the download and/or failure to download.

6. Notify Response

The software update server **1200** may respond with a notify response message **1214** in response to the download notify message **1212** or an update notify message **1216**. The notify response message **1214** may include the status reporting format, as described above. For example, the notify response message **1214** may include status codes as enumerated in Table 16 below.

TABLE 16

Example notify response status codes		
Profile	Code	Description
0x00000000	0x0030	Continue - the notification is acknowledged, but the update has not completed, such as download notify message 1214 received but update notify message 1216 has not.
0x00000000	0x0000	Success - the notification is acknowledged, and the update has completed.
0x0000000C	0x0023	Abort - the notification is acknowledged, but the server cannot continue the update.
0x0000000C	0x0031	Retry query - the notification is acknowledged, and the software update client 1198 is directed to retry the update by submitting another image query message 1206.

In addition to the status reporting described above, the notify response message **1214** may include additional status information that may be relevant to the download, update, and/or failure to download/update the software update.

7. Update Notify

After the update is successfully completed or failed and the report status flag **1280** value is 1, the software update client **1198** may respond with the update notify message **1216**. The update notify message **1216** may use the status reporting format described above. For example, the update notify message **1216** may include status codes as enumerated in Table 17 below.

TABLE 17

Example update notify status codes		
Profile	Code	Description
0x00000000	0x0000	Success - the update has been completed.
0x0000000C	0x0010	Client error - the update failed due to a problem in the software update client 1198.

In addition to the status reporting described above, the update notify message **1216** may include additional status information that may be relevant to the update and/or failure to update.

C. Bulk Transfer

In some embodiments, it may be desirable to transfer bulk data files (e.g., sensor data, logs, or update images) between nodes/services in the fabric **1000**. To enable transfer of bulk data, a separate profile or protocol may be incorporated into one or more profiles and made available to the nodes/services in the nodes. The bulk data transfer protocol may model data files as collections of data with metadata attachments. In certain embodiments, the data may be opaque, but the metadata may be used to determine whether to proceed with a requested file transfer.

Devices participating in a bulk transfer may be generally divided according to the bulk transfer communication and event creation. As illustrated in FIG. **31**, each communication **1400** in a bulk transfer includes a sender **1402** that is a node/service that sends the bulk data **1404** to a receiver **1406** that is a node/service that receives the bulk data **1404**. In some embodiments, the receiver may send status information **1408** to the sender **1402** indicating a status of the bulk transfer. Additionally, a bulk transfer event may be initiated by either the sender **1402** (e.g., upload) or the receiver **1406** (e.g., download) as the initiator. A node/service that responds to the initiator may be referred to as the responder in the bulk data transfer.

Bulk data transfer may occur using either synchronous or asynchronous modes. The mode in which the data is transferred may be determined using a variety of factors, such as the underlying protocol (e.g., UDP or TCP) on which the bulk data is sent. In connectionless protocols (e.g., UDP), bulk data may be transferred using a synchronous mode that allows one of the nodes/services ("the driver") to control a rate at which the transfer proceeds. In certain embodiments, after each message in a synchronous mode bulk data transfer, an acknowledgment may be sent before sending the next message in the bulk data transfer. The driver may be the sender **1402** or the receiver **1406**. In some embodiments, the driver may toggle between an online state and an offline mode while sending messages to advance the transfer when in the online state. In bulk data transfers using connection-oriented protocols (e.g., TCP), bulk data may be transferred using an asynchronous mode that does not use an acknowledgment before sending successive messages or a single driver.

Regardless of whether the bulk data transfer is performed using a synchronous or asynchronous mode, a type of message may be determined using a Message Type **1172** in the Application Payload **1146** according the Profile Id **1176** in the Application Payload. Table 18 includes an example of message types that may be used in relation to a bulk data transfer profile value in the Profile Id **1176**.

TABLE 18

Example of profile message types for bulk data transfer profiles	
Type	Message
0x01	snapshot request
0x02	watch request
0x03	periodic update request
0x04	refresh update
0x05	cancel view update
0x06	view response
0x07	explicit update request

TABLE 18-continued

Example of profile message types for bulk data transfer profiles	
Type	Message
0x08	view update request
0x09	Block EOF
0x0A	Ack
0x0B	Block EOF
0x0C	Error

i. SendInit

An embodiment of a SendInit message **1420** is illustrated in FIG. **32**. The SendInit message **1420** may include seven fields: a transfer control field **1422**, a range control field **1424**, a file designator length field **1426**, a proposed max block size field **1428**, a start offset field **1430**, length field **1432**, and a file designator field **1434**.

The transfer control field **1422** includes a byte of data illustrated in FIG. **33**. The transfer control field includes at least four fields: an Asynch flag **1450**, an RDrive flag **1452**, an SDrive flag **1454**, and a version field **1456**. The Asynch flag **1450** indicates whether the proposed transfer may be performed using a synchronous or an asynchronous mode. The RDrive flag **1452** and the SDrive flag **1454** each respectively indicates whether the receiver **1406** is capable of transferring data with the receiver **1402** or the sender **1408** driving a synchronous mode transfer.

The range control field **1424** includes a byte of data such as the range control field **1424** illustrated in FIG. **34**. In the illustrated embodiment, the range control field **1424** includes at least three fields: a BigExtent flag **1470**, a start offset flag **1472**, and a definite length flag **1474**. The definite length flag **1474** indicates whether the transfer has a definite length. The definite length flag **1474** indicates whether the length field **1432** is present in the SendInit message **1420**, and the BigExtent flag **1470** indicates a size for the length field **1432**. For example, in some embodiments, a value of 1 in the BigExtent flag **1470** indicates that the length field **1432** is eight bytes. Otherwise, the length field **1432** is four bytes, when present. If the transfer has a definite length, the start offset flag **1472** indicates whether a start offset is present. If a start offset is present, the BigExtent flag **1470** indicates a length for the start offset field **1430**. For example, in some embodiments, a value of 1 in the BigExtent flag **1470** indicates that the start offset field **1430** is eight bytes. Otherwise, the start offset field **1430** is four bytes, when present.

Returning to FIG. **32**, the file designator length field **1426** includes two bytes that indicate a length of the file designator field **1434**. The file designator field **1434** which is a variable length field dependent upon the file designator length field **1426**. The max block size field **1428** proposes a maximum size of block that may be transferred in a single transfer.

The start offset field **1430**, when present, has a length indicated by the BigExtent flag **1470**. The value of the start offset field **1430** indicates a location within the file to be transferred from which the sender **1402** may start the transfer, essentially allowing large file transfers to be segmented into multiple bulk transfer sessions.

The length field **1432**, when present, indicates a length of the file to be transferred if the definite length field **1474** indicates that the file has a definite length. In some embodiments, if the receiver **1402** receives a final block before the length is achieved, the receiver may consider the transfer failed and report an error as discussed below.

The file designator field **1434** is a variable length identifier chosen by the sender **1402** to identify the file to be sent. In some embodiments, the sender **1402** and the receiver **1406** may negotiate the identifier for the file prior to transmittal. In other embodiments, the receiver **1406** may use metadata along with the file designator field **1434** to determine whether to accept the transfer and how to handle the data. The length of the file designator field **1434** may be determined from the file designator length field **1426**. In some embodiments, the SendInit message **1420** may also include a metadata field **1480** of a variable length encoded in a TLV format. The metadata field **1480** enables the initiator to send additional information, such as application-specific information about the file to be transferred. In some embodiments, the metadata field **1480** may be used to avoid negotiating the file designator field **1434** prior to the bulk data transfer.

ii. SendAccept

A send accept message is transmitted from the responder to indicate the transfer mode chosen for the transfer. An embodiment of a SendAccept message **1500** is presented in FIG. **35**. The SendAccept message **1500** includes a transfer control field **1502** similar to the transfer control field **1422** of the SendInit message **1420**. However, in some embodiments, only the RDrive flag **1452** or the SDrive **1454** may have a nonzero value in the transfer control field **1502** to identify the sender **1402** or the receiver **1406** as the driver of a synchronous mode transfer. The SendAccept message **1500** also includes a max block size field **1504** that indicates a maximum block size for the transfer. The block size field **1504** may be equal to the value of the max block field **1428** of the SendInit message **1420**, but the value of the max block size field **1504** may be smaller than the value proposed in the max block field **1428**. Finally, the SendAccept message **1500** may include a metadata field **1506** that indicates information that the receiver **1506** may pass to the sender **1402** about the transfer.

iii. SendReject

When the receiver **1206** rejects a transfer after a SendInit message, the receiver **1206** may send a SendReject message that indicates that one or more issues exist regarding the bulk data transfer between the sender **1202** and the receiver **1206**. The send reject message may be formatted according to the status reporting format described above and illustrated in FIG. **36**. A send reject frame **1520** may include a status code field **1522** that includes two bytes that indicate a reason for rejecting the transfer. The status code field **1522** may be decoded using values similar to those enumerated as indicated in the Table 19 below.

TABLE 19

Example status codes for send reject message	
Status Code	Description
0x0020	Transfer method not supported
0x0021	File designator unknown
0x0022	Start offset not supported
0x0011	Length required
0x0012	Length too large
0x002F	Unknown error

In some embodiments, the send reject message **1520** may include a next status field **1524**. The next status field **1524**, when present, may be formatted and encoded as discussed above in regard to the next status field **1188** of a status report frame. In certain embodiments, the send reject message

1520 may include an additional information field **1526**. The additional information field **1526**, when present, may store information about an additional status and may be encoded using the TLV format discussed above.

iv. ReceiveInit

A ReceiveInit message may be transmitted by the receiver **1206** as the initiator. The ReceiveInit message may be formatted and encoded similar to the SendInit message **1480** illustrated in FIG. **32**, but the BigExtent field **1470** may be referred to as a maximum length field that specifies the maximum file size that the receiver **1206** can handle.

v. ReceiveAccept

When the sender **1202** receives a ReceiveInit message, the sender **1202** may respond with a ReceiveAccept message. The ReceiveAccept message may be formatted and encoded as the ReceiveAccept message **1540** illustrated in FIG. **37**. The ReceiveAccept message **1540** may include four fields: a transfer control field **1542**, a range control field **1544**, a max block size field **1546**, and sometimes a length field **1548**. The ReceiveAccept message **1540** may be formatted similar to the SendAccept message **1502** of FIG. **35** with the second byte indicating the range control field **1544**. Furthermore, the range control field **1544** may be formatted and encoded using the same methods discussed above regarding the range control field **1424** of FIG. **34**.

vi. ReceiveReject

If the sender **1202** encounters an issue with transferring the file to the receiver **1206**, the sender **1202** may send a ReceiveReject message formatted and encoded similar to a SendReject message **48** using the status reporting format, both discussed above. However, the status code field **1522** may be encoded/decoded using values similar to those enumerated as indicated in the Table 20 below.

TABLE 20

Example status codes for receive reject message

Status Code	Description
0x0020	Transfer method not supported
0x0021	File designator unknown
0x0022	Start offset not supported
0x0013	Length too short
0x002F	Unknown error

vii. BlockQuery

A BlockQuery message may be sent by a driving receiver **1202** in a synchronous mode bulk data transfer to request the next block of data. A BlockQuery impliedly acknowledges receipt of a previous block of data if not explicit Acknowledgement has been sent. In embodiments using asynchronous transfers, a BlockQuery message may be omitted from the transmission process.

viii. Block

Blocks of data transmitted in a bulk data transfer may include any length greater than 0 and less than a max block size agreed upon by the sender **1202** and the receiver **1206**.

ix. BlockEOF

A final block in a data transfer may be presented as a Block end of file (BlockEOF). The BlockEOF may have a length between 0 and the max block size. If the receiver **1206** finds a discrepancy between a pre-negotiated file size (e.g., length field **1432**) and the amount of data actually transferred, the receiver **1206** may send an Error message indicating the failure, as discussed below.

x. Ack

If the sender **1202** is driving a synchronous mode transfer, the sender **1202** may wait until receiving an acknowledgment (Ack) after sending a Block before sending the next Block. If the receiver is driving a synchronous mode transfer, the receiver **1206** may send either an explicit Ack or a BlockQuery to acknowledge receipt of the previous block. Furthermore, in asynchronous mode bulk transfers, the Ack message may be omitted from the transmission process altogether.

xi. AckEOF

An acknowledgement of an end of file (AckEOF) may be sent in bulk transfers sent in synchronous mode or asynchronous mode. Using the AckEOF the receiver **1206** indicates that all data in the transfer has been received and signals the end of the bulk data transfer session.

xii. Error

In the occurrence of certain issues in the communication, the sender **1202** or the receiver **1206** may send an error message to prematurely end the bulk data transfer session. Error messages may be formatted and encoded according to the status reporting format discussed above. For example, an error message may be formatted similar to the SendReject frame **1520** of FIG. **36**. However, the status codes may be encoded/decoded with values including and/or similar to those enumerated in Table 21 below.

TABLE 21

Example status codes for an error message in a bulk data transfer profile

Status code	Description
0x001F	Transfer failed unknown error
0x0011	Overflow error

D. Time Variant Data Profile

Time-variant data profile may be used for reporting and exchanging time-variant historical data among endpoints within a smart network. In some embodiments, at least a portion of the role of any device in the smart network is to observe and record the environment of which the device is a part. This observation and reporting is done over time and reporting those time-variant historical observations to other endpoints in the smart network. The time-variant data profile defines a set of tags and data values for exchanging these time-variant historical observations atop the bulk data transfer protocol. In some embodiments, this profile has an identified profile identifier that indicates that a communication includes data in the time-variant data profile

While it is possible to exchange time-variant data using the bulk data transfer protocol as opaque, binary data, it may be desirable to exchange such data in a way to enable a pipeline of backend consumers and applications for the data. Consequently, tagging or marking up the data in a well-known format provides scale in both the number of data producers as well as consumers without invasive or disruptive redefinition of the encoders and decoders used for the data.

Time-variant data in this profile is tagged using the tag-length-value (TLV) Format. As previously discussed, the structure defined and imposed by the TLV amounts to a small read-only section at the “front” of a time-variant exchange that describe the data streams at the “back.” In some embodiments, the format may be trivially transformed to other representations such as JSON or XML for backend consumption and processing. Moreover, the data may be represented in a known byte order (e.g., big endian or little endian) to provide for ease of conversion and interpretation.

a. Stream Structures

A time-variant data exchange **1632** is organized as nested set of structures, as illustrated in FIG. **38**. At the outermost nesting level is the overall streams structure **1634** that marks the overall time-variant data exchange **1632**. Contained within the streams structure **1634** is a single version element **1636**, a description field **1638**, a resources element **1640**, descriptors arrays **1642**, and records arrays **1644**. The version element **1636** is a value (e.g., 8-bit unsigned fixed-point integer) that indicates the version of the structure described within the streams container **1634**. For example, in some embodiments, the version may be a 1 for the first version.

The description field **1638** includes a human readable string that describes the entire time variant stream. In some embodiments, the description field **1638** may be formatted as a UTF-8 string. In some embodiments, the description field **1638** may be advisory and/or informative for later analysis. Moreover, in some embodiments, the description field **1638** may be omitted from at least some broadcasted messages.

The resources element **1640** inside the streams structure **1634** is an optional element that contains an array of one or more URI elements **1646** that map to resources to be fetched while parsing the streams structure **1634**. In some embodiments, URI elements **1646** are strings. In some embodiments, the URIs **1646** may also include an identification of a path that identifies the time-variant data element into which the data is to be imported. When importing array data from multiple locations into the same destination array, the multiple source arrays may be concatenated together in the order the resource elements **1640**.

In some embodiments, URI elements **1648** shared between vendors/public descriptors may also be URLs. In such scenarios, the service that would return the resources requested by providing these URLs may set an appropriate MIME type that is an indicator of the encoding of the resource fetched. For example, if the resource is encoded as a TLV element, the appropriate MIME type may be "application/vnd.nest.weave.tvd+tlv". Table 22 provides examples of possible MIME types

TABLE 22

Example MIME types

Resource Encoding	MIME Type
TLV	application/vnd.<vendor>.weave.tvd+tlv
JSON	application/vnd.<vendor>.weave.tvd+json
XML	application/vnd.<vendor>.weave.tvd+xml

Each of these external resources that are imported may be decoded into an array of descriptor elements **1642**. Resources element **1640** can have multiple descriptors elements which could point to resources that have intersecting descriptor elements **1654**.

The imported resources, decode into the descriptors elements equivalent to the descriptor elements **1654** in the descriptors array **1642** inside the parent streams element **1634**. The descriptors element **1642** includes one or more descriptor structures **1654** that includes metadata describing the data contained within the following records structure element **1644**. The records structure element **1644** includes one or more record structures **1656**, which represents the historical time-variant data samples being exchanged. Moreover, each descriptor structure **1654** is correlated to a corresponding record structure **1656** through a key/value pairs shared within respective structures through respective identifier fields **1658**.

Resources element **1654** inside the streams element **1634** can contain multiple URIs that import different sets of descriptors. Also, a streams element **1634** can contain inline descriptors arrays **1642** that have intersecting/non-interacting descriptors. In some embodiments, the URI may include a vendor identifier and a product identifier. For example, the URI might include http://tlvsite.com/0x235A/0x0005/85a14e9.tlv. Furthermore, certain constraints may be placed on the URIs. For example, in some embodiments, URIs may contain domain information as an identifier of vendor and domain information should be in lower cased. (e.g http://www.tlvsite.com/tvd/ or http://tvd.tlvsite.com/). Moreover, in certain embodiments, the URIs may contain the product name, product version, and/or a schema version or a unique identifier for the resource like a SHA1# of the resource (e.g., http://tlvsite.com/tvd/hazard_detector/t1/#85a14e9 or http://hazard_detector.tvd.tlvsite.com/#85a14e9). In some embodiments, the URIs may constrain use of delimiter characters, such as "/", in the identifier of the resource. In some embodiments, the URIs may have an extension to specify encoding of the resource (e.g http://hazard_detector.tvd.tlvsite.com/85a14e9.tlv). In some embodiments, public URLs may include vendorId and productId for namespacing (e.g http://tvd.tlvsite.com/235A/5/85a14e9.tlv).

Some resources that are imported may be decoded into an External Descriptors element that may be parsed independently from and interpreted outside the Streams object **1632**. FIG. **39** illustrates a possible structure for an External Descriptor **1648**, in accordance with an embodiment. As illustrated, the External Descriptor structure **1648** includes an array of one or more Descriptor elements **1650**. These Descriptor elements **1650** may be similar in structure to the Descriptors **1642**, but the External Descriptors array **1648** may be encoded with a Top Level Profile Tag (e.g., ExtDescriptor tag) with each Descriptor **1650** therein having a context tag to maintain context specific interpretation of the Descriptor elements **1642**. In certain embodiments, the External Descriptors **1650** may be formatted in any suitable format. However, in some embodiments, a TLV encoding may be used to maintain consistency between imported elements and inline elements already present. In some embodiments, when external resources are requested by their URIs the service that returns these external descriptors. The Table 23 below provides example tags used by this profile to format data. Each tag is subsequently described in detail.

TABLE 23

Example tags for the time-variant profile

Name	Tag Type	Element Type	Value
Resources	Context	Array	0x23
URI	Context	String	0x24
ExtDescriptors	Fully Qualified	Array	0x02

The following Table 24 provides example external descriptor values:

TABLE 24

Example external descriptor values				
Element	Notes	Tag	Length	Value
Descriptors (parent)	Start of Descriptors	0xD5 23 5 A 00 04 00 02	—	—
Descriptor	Start of Descriptor	0x15	—	—
Identifier	1	0x25 05	0x02	0x00 01
Stream Periodicity	True	0x29 0A	—	—
Type	Temperature	0x25 06	0x02	0x00 05
Fields	Start of Fields	0x36 0C	—	—
Field	Start of Field	0x15	—	—
Valid	True	0x29 0E	—	—
Relative	False	0x28 0F	—	—
Signed	True	0x29 10	—	—
Size	15-bits	0x24 11	0x01	0x10
Count	1	0x24 13	0x01	0x01
Exponent	−1	0x20 18	0x01	0xFF
Units	Start of Units	0x35 14	—	—
System	SI	0x24 15	0x01	0x01
Description	"° C."	0x2C 09	0x03	0xC2 B0 43
Units	Start of Units	0x36 14	—	—
Unit	Start of Unit	0x35 16	—	—
Quantity	Temperature	0x24 17	0x01	0x05
End of Container	End of Unit	0x18	—	—
End of Container	End of Units	0x18	—	—
End of Container	End of Units	0x18	—	—
End of Container	End of Field	0x18	—	—
Field	Start of Field	0x15	—	—
Valid	False	0x28 0F	—	—
Size	1-bit	0x24 12	0x01	0x01
Count	1	0x24 13	0x01	0x01
End of Container	End of Field	0x18	—	—
End of Container	End of Fields	0x18	—	—
Description	"Temperature"	0x2C 09	0x0B	0x54 65 6D 70 65 72 61 74 75 72 65
Time Base	Start of Time Base	0x35 1F	—	—
Reference	Monotonic	0x24 21	0x01	0x00
Exponent	0	0x20 18	0x01	0x00
Synchronization	Unsynchronized	0x24 22	0x01	0x02
End of Container	End of Timer Base	0x18	—	—
Time Period	Start of Time Period	0x35 0B	—	—
Exponent	0	0x20 18	0x01	0x00
End of Container	End of Time Period	0x18	—	—
End of Container	End of Descriptor	0x18	—	—
End of Container	End of ExtDescriptors	0x18	—	—

The following Table 25 provides example values for imported descriptors.

TABLE 25

Example imported descriptors.				
Element	Notes	Tag	Length	Value
Streams	Start of Streams	0xD5 23 5 A 00 04 00 01	—	—
Version	1	0x24 02	0x01	0x01
Resources	Start of Descriptors	0x36 23	—	—
URI	String (http://tlvsite.com/tvd/235A/5/a33d424)	0x24	0x22	0x68 74 74. . . 32 34 0a
URI	String (http://tlvsite.com/tvd/235A/5/3d42434))	0x24	0x22	0x68 74 74. . . 33 32 0a

TABLE 25-continued

Example imported descriptors.				
Element	Notes	Tag	Length	Value
End of Container	End of Resources	0x18	—	—
Records	Start of Records	0x36 1D	—	—
Stream	Start of Stream	0x35 1E	—	—
Identifier	1	0x25 05	0x00 01	
Time Period	10	0x24 0B	0x01	0x0A
Time Base	11	0x22 1F	0x04	0x00 00 00 0B
Data	21.7° C., 22.2° C., . . . 23.3° C.	0x31 1E	0x0B 40	0x00 D9 00 DE . . . 00 E9
End of Container	End of Stream	0x18	—	—
End of Container	End of Records	0x18	—	—
End of Container	End of Streams	0x18	—	—

The following Table 26 provides example values for inline descriptors.

TABLE 26

Example inline descriptors.				
Element	Notes	Tag	Length	Value
Streams	Start of Streams	0xD5 23 5 A 00 04 00 01	—	—
Version	1	0x24 02	0x01	0x01
Descriptors	Start of Descriptors	0x36 03	—	—
Descriptor	Start of Descriptor	0x15	—	—
Identifier	1	0x25 05	0x02	0x00 01
Stream Periodicity	True	0x29 0A	—	—
Type	Temperature	0x25 06	0x02	0x00 05
Fields	Start of Fields	0x36 0C	—	—
Field	Start of Field	0x15	—	—
Valid	True	0x29 0E	—	—
Relative	False	0x28 0F	—	—
Signed	True	0x29 10	—	—
Size	15-bits	0x24 11	0x01	0x10
Count	1	0x24 13	0x01	0x01
Exponent	−1	0x20 18	0x01	0xFF
Units	Start of Units	0x35 14	—	—
System	SI	0x24 15	0x01	0x01
Description	"° C."	0x2C 09	0x03	0xC2 B0 43
Units	Start of Units	0x36 14	—	—
Unit	Start of Unit	0x35 16	—	—
Quantity	Temperature	0x24 17	0x01	0x05
End of Container	End of Unit	0x18	—	—
End of Container	End of Units	0x18	—	—
End of Container	End of Units	0x18	—	—
End of Container	End of Field	0x18	—	—
Field	Start of Field	0x15	—	—
Valid	False	0x28 0F	—	—
Size	1-bit	0x24 12	0x01	0x01
Count	1	0x24 13	0x01	0x01
End of Container	End of Field	0x18	—	—
End of Container	End of Fields	0x18	—	—
Description	"Temperature"	0x2C 09	0x0B	0x54 65 6D 70 65 72 61 74 75 72 65
Time Base	Start of Time Base	0x35 1F	—	—
Reference	Monotonic	0x24 21	0x01	0x00
Exponent	0	0x20 18	0x01	0x00
Synchronization	Unsynchronized	0x24 22	0x01	0x02

TABLE 26-continued

Example inline descriptors.

Element	Notes	Tag	Length	Value
End of Container	End of Timer Base	0x18	—	—
Time Period	Start of Time Period	0x35 0B	—	—
Exponent	0	0x20 18	0x01	0x00
End of Container	End of Time Period	0x18	—	—
End of Container	End of Descriptor	0x18	—	—
End of Container	End of Descriptors	0x18	—	—
Records	Start of Records	0x36 1D	—	—
Stream	Start of Stream	0x35 1E	—	—
Identifier	1	0x25 05	0x00 01	
Time Period	10	0x24 0B	0x01	0x0A
Time Base	11	0x22 1F	0x04	0x00 00 00 0B
Data	21.7° C., 22.2° C., . . . 23.3° C.	0x31 1E	0x0B 40	0x00 D9 00 DE . . . 00 E9
End of Container	End of Stream	0x18	—	—
End of Container	End of Records	0x18	—	—
End of Container	End of Streams	0x18	—	—
Total Size	—	86	20	5,797

Table 27 below provides example values for imported plus inline descriptors.

TABLE 27

Example imported plus inline descriptors.

Element	Notes	Tag	Length	Value
Streams	Start of Streams	0xD5 23 5 A 00 04 00 01	—	—
Version	1	0x24 02	0x01	0x01
Resources	Start of Descriptors	0x36 23	—	—
URI	String (http://tlvsite.com/tvd/235A/5/a33d424)	0x24	0x22	0x68 74 74. . . 32 34 0a
URI	String (http://tlvsite.com/tvd/235A/5/3d42434))	0x24	0x22	0x68 74 74. . . 33 32 0a
End of Container	End of Resources	0x18	—	—
Descriptors	Start of Descriptors	0x36 03	—	—
Descriptor	Start of Descriptor	0x15	—	—
Identifier	1	0x25 05	0x02	0x00 01
Stream Periodicity	True	0x29 0A	—	—
Type	Temperature	0x25 06	0x02	0x00 05
Fields	Start of Fields	0x36 0C	—	—
Field	Start of Field	0x15	—	—
Valid	True	0x29 0E	—	—
Relative	False	0x28 0F	—	—
Signed	True	0x29 10	—	—
Size	15-bits	0x24 11	0x01	0x10
Count	1	0x24 13	0x01	0x01
Exponent	−1	0x20 18	0x01	0xFF
Units	Start of Units	0x35 14	—	—
System	SI	0x24 15	0x01	0x01
Description	"° C."	0x2C 09	0x03	0xC2 B0 43
Units	Start of Units	0x36 14	—	—
Unit	Start of Unit	0x35 16	—	—

TABLE 27-continued

Example imported plus inline descriptors.

Element	Notes	Tag	Length	Value
Quantity	Temperature	0x24 17	0x01	0x05
End of Container	End of Unit	0x18	—	—
End of Container	End of Units	0x18	—	—
End of Container	End of Units	0x18	—	—
End of Container	End of Field	0x18	—	—
Field	Start of Field	0x15	—	—
Valid	False	0x28 0F	—	—
Size	1-bit	0x24 12	0x01	0x01
Count	1	0x24 13	0x01	0x01
End of Container	End of Field	0x18	—	—
End of Container	End of Fields	0x18	—	—
Description	"Temperature"	0x2C 09	0x0B	0x54 65 6D 70 65 72 61 74 75 72 65
Time Base	Start of Time Base	0x35 1F	—	—
Reference	Monotonic	0x24 21	0x01	0x00
Exponent	0	0x20 18	0x01	0x00
Synchronization	Unsynchronized	0x24 22	0x01	0x02
End of Container	End of Timer Base	0x18	—	—
Time Period	Start of Time Period	0x35 0B	—	—
Exponent	0	0x20 18	0x01	0x00
End of Container	End of Time Period	0x18	—	—
End of Container	End of Descriptor	0x18	—	—
End of Container	End of Descriptors	0x18	—	—
Records	Start of Records	0x36 1D	—	—
Stream	Start of Stream	0x35 1E	—	—
Identifier	1	0x25 05	—	0x00 01
Time Period	10	0x24 0B	0x01	0x0A
Time Base	11	0x22 1F	0x04	0x00 00 00 0B
Data	21.7 °C3, 22.2 °C., . . . 23.3°C.	0x31 1E	0x0B 40	0x00 D9 00 DE . . . 00 E9
End of Container	End of Stream	0x18	—	—
End of Container	End of Records	0x18	—	—
End of Container	End of Streams	0x18	—	—

i. Descriptor Structure

The descriptor structure **1654** is a collection of data describing the data contained within the associated record structure **1656** and may be generally formatted as depicted below in FIG. **43**. As previously discussed, the device descriptor **1654** includes the identifier element **1658**. The identifier element is a caller-assigned 16-bit unsigned fixed-point value that is used to uniquely identify a particular sequence within the time-variant data exchange and to correlate a descriptor with its associated data in the stream.

The descriptor structure **1654** also includes a stream periodicity element **1660** is a Boolean flag that is used to indicate whether the descriptor structure **1654** and the associated data stream are periodic or aperiodic. When stream periodicity element **1660** is false, the stream is aperiodic and the data stream may be represented in tuples. The first element of each tuple, when specified, represents a relative or absolute time when the data sample(s) were taken. When stream periodicity element **1660** is true, the stream is periodic and the data stream is interpreted as values sampled at precise and evenly spaced intervals in time. The sampling period will be described by a period element within the descriptor structure, discussed below.

The descriptor structure **1654** further includes a type element **1662**. The type element **1662** is a caller-assigned 16-bit or 32-bit unsigned fixed-point value that represents the type of sample in a particular data stream. The type element **1662** applies to any and all field elements **1664** found in the descriptor structure **1654** unless explicitly overridden by another type element **1662** contained within a field element **1664**.

In some embodiments, values in the range 0-65 and 535 are reserved and selected for use from those listed below in Table 28.

TABLE 28

Types defined for data streams.

Value(s)	Description
0x0000	None
0x0001	Length
0x0002	Mass
0x0003	Time
0x0004	Current
0x0005	Temperature
0x0006	Luminous Intensity
0x0007	Area
0x0008	Volume
0x0009	Velocity
0x000A	Acceleration
0x000B	Density
0x000C	Current Density
0x000D	Magnetic Field Strength
0x000E	Luminance
0x000F	Mass Concentration
0x0010	Molar Concentration
0x0011	Number Concentration
0x0012	Volume Concentration
0x0013	Normality
0x0014	Molality
0x0015	Mole Fraction
0x0016	Mole Ratio
0x0017	Mass Fraction
0x0018	Mass Ratio
0x0019	Plane Angle
0x001A	Solid Angle
0x001B	Frequency
0x001C	Force
0x001D	Pressure
0x001E	Energy
0x001F	Power
0x0020	Electric Charge
0x0021	Electric Potential
0x0022	Capacitance
0x0023	Electric Resistance
0x0024	Electric Conductance
0x0025	Magnetic Flux
0x0026	Magnetic Flux Density
0x0028	Inductance
0x0029	Luminous Flux
0x002A	Illuminance
0x002B	Radioactivity
0x002C	Depth
0x002D	Height
0x002E	Humidity
0x002F	Distance
0x0030	Opacity
0x0031	Attenuation
0xFFFE-0x0031	Reserved for future use.
0xFFFF	Other
0xFFFE FFFF-0x0001 0000	Reserved for vendor use.
0xFFFF FFFF-0xFFFF 0000	Reserved.

In some embodiments, vendors may create their own values for this element in the 32-bit range by qualifying the name space with a vendor identifier in the upper 16-bits and using any value in the lower 16-bits.

The descriptor structure **1654** may also include a description element **1666**. The description element **1666** is a caller-assigned, human-readable UTF-8 string that may be used to describe a particular stream. The description element **1666** may apply to any and all field elements **1664** found in the descriptor structure **1654** unless explicitly overridden by another description element contained within a field element **1664**. In some embodiments, the description element **1666** may be omitted from some instances of the descriptor structure **1654**.

As discussed above, the descriptor structure **1654** may also include a derivation element **1668**, a time base element **1670**, and a time period element **1672**. The derivation element **1668** is a structure used to indicate that a mathematical operation was applied to the data stream to arrive at the exchanged data. FIG. **41** illustrates an embodiment of the derivation element **1668**. The derivation element **1668** applies to any field elements **1664** found in the descriptor structure **1654** unless explicitly overridden by another derivation element **1668** contained within a field element **1664**. The derivation element **1668** includes an operations element **1674** is a array that contains one or more operation sub-elements **1676** describing mathematical operations or transformations that have been applied to the data samples in the corresponding stream structure. The operation sub-element **1676** is a caller-assigned 16-bit or 32-bit unsigned fixed-point value that represents a mathematical operation that was applied to achieve the sample derivation. For example, the operations may be indexed similarly to the values reproduced below in Table 29.

TABLE 29

Operations defined for data streams.

Value(s)	Description
0x0000	None
0x0001	Minimum
0x0002	Maximum
0x0003	Mean
0x0004	Mode
0x0005	Median
0x0006	Logarithm-Base 2
0x0007	Logarithm-Base e
0x0008	Logarithm-Base 10
0x0009	Quadratic Mean
0xFFFE-0x000A	Reserved for future use.
0xFFFF	Other
0xFFFE FFFF-0x0001 0000	Reserved for vendor use.
0xFFFF FFFF-0xFFFF 0000	Reserved.

In some embodiments, vendors may create their own values for this element in the 32-bit range by qualifying the name space with a vendor identifier in the upper 16-bits and using any value in the lower 16-bits.

The derivation element **1668** also includes an identifier element **1678**. The identifier element **1658** is a caller-assigned 16-bit unsigned fixed-point value that is to correlate the derivation back to another base descriptor structure **1654**/stream. In some embodiments, the identifier element **1678** may be omitted from the derivation element **1668** and instead use the identifier element **1658** of the descriptor structure **1654** of the derivation element **1668**.

Returning to FIG. **40**, the fields element **1664** is an array that contains or one or more field structures **1680** describing the format of the data samples found in a corresponding stream structure. The field structure **1680** is a structured collection of metadata describing a stride of the data in an associated stream element and may be structured as illustrated in FIG. **42**. Several of the fields describe how to compute both the resolution of the sample data as well as a linear transformation on each data sample to arrive at a physical value from a logical value. As discussed below, the fields used for these computations may include an exponent field, a minimum field, a logical maximum field, a physical minimum, and a physical maximum, among other fields. The resolution may be derived as shown in Equation 1 below:

$$\text{Resolution} = \frac{\text{Logical Maximum} - \text{Logical Minimum}}{\text{Physical Maximum} - \text{Physical Minimum}} \times 10^{Exponent}, \quad \text{(Equation 1)}$$

The linear transformation may be applied as shown in Equation 2 below:

$$\text{Physical}_i = \left(\frac{\left((\text{Logical}_i - \text{Logical Minimum}) \times (\text{Physical Maximum} - \text{Physical Minimum}) \right)}{(\text{Logical Maximum} - \text{Logical Minimum})} + \text{Physical Minimum} \right) \times 10^{Exponent}, \quad \text{(Equation 2)}$$

The field structure **1680** may include a valid element **1682**. The valid element **1682** is a Boolean flag used to indicate whether or not the field contains alignment padding or valid data. When the valid element **1682** is false, the field contains padding and may be ignored, regardless of value. When valid element **1682** is true, the field contains a valid data sample.

The field structure **1680** may include may also include a relative element **1684**. The relative element **1684** is a conditional Boolean value that may be omitted when the valid element **1682** is false. When present, the relative element **1684** may be used to indicate whether or not the field contains absolute or relative measurements.

When relative element **1684** is false, the field structure **1680** contains data that is absolute and may be interpreted without consideration of any prior samples. When the relative element **1684** is true, the field structure **1680** contains data that is relative to be interpreted in the context of the samples that preceded it.

The field structure **1680** may also include a signed element **1686**. The signed element **1686** is a conditional Boolean flag that may be omitted when the valid element **1682** is false. When present, the signed element **1686** may be used to indicate whether or not the field contains unsigned or signed data. When the signed element **1686** is false, the field contains unsigned data. When the signed element **1686** is true, the field contains signed data. In some embodiments, the signed data may be two's complement data.

The field structure **1680** may include a size element **1688** and a count element **1690**. The size element is an 8-bit unsigned fixed-point value that indicates the size of a corresponding data value. In some embodiments, the size may be represented in bits or bytes. The count element **1690** is a required 8-bit unsigned fixed-point value that indicates the number of size elements **1688** for the field.

In some embodiments, the count element **1690** may be one. However, the count element **1690** provides a means by which to represent tuple streams, such as a RGB tuple from a multi-color luminance sensor. In some embodiments, the size and count elements **1688** and **1690** may be specified such that individual fields achieve alignments of precisely 1 byte, 2 bytes, or 4*k bytes, where k is a positive integer.

The field structure **1680** may also include an exponent element **1692**. The exponent element **1692** is an optional 8-bit signed or unsigned fixed-point value that represents the exponent applicable to the data samples. In some embodiments, the exponent may be represented in base 10. This element provides a way to scale data to preserve resolution or to avoid floating-point representation. Equations 1 and 2 above demonstrate how the exponent element **1692** may be used to transform each data sample. In some embodiments, an omitted exponent element **1692** implies an exponent of 0 (e.g., $10^0=1$). For example, to communicate a range of values 0.0 to 150.0 with significance to the tenths, the values could be exchanged with the logical range 0 to 1500 with an exponent element **1692** value of −1 (e.g., $10^{-1}=1/10$).

The field structure **1680** may also include a logical minimum element **1694**. The logical minimum element **1694** is a fixed-point value that indicates the minimum expected, valid logical value for the field. Equations 1 and 2 above demonstrate how this value is used to transform each data sample. When the logical minimum element **1694** is absent, the implied value for this field is the minimum valid representation based on the size and signed field elements **1686** and **1688**. The field structure **1680** may also include a similar a logical maximum element **1696** as a fixed-point value that indicates the maximum expected, valid logical value for the field. When the logical maximum element **1696** is absent, the implied value is the maximum valid representation for the field based on the size and signed field elements **1686** and **1688**. When one or both of these values is present, data samples outside of the range are invalid and should be ignored.

The field structure **1680** may also include a physical minimum element **1698** and a physical maximum element **1700**. The physical minimum element **1698** is a fixed-point value that indicates the minimum expected and valid physical value for the field. When the physical minimum element **1698** is absent, the implied value field is the literal or implied value of logical minimum element **1694**. Equations 1 and 2 above demonstrate how this value is used to transform each data sample. The physical maximum element **1700** is a fixed-point value that indicates the maximum expected and valid physical value for the field. Equations 1 and 2 above demonstrate how this value is used to transform each data sample. When the physical maximum element **1700** is absent, the implied value is the literal or implied value of logical maximum element **1696**.

The field structure **1680** may also include a units element **1702**, a description element **1704**, a type element **1706**, and a derivation element **1708**. The units element **1702** is an advisory structured collection of metadata describing the units associated with the physical values represented by data samples and may be structured as illustrated in FIG. **43**.

The units element **1702** includes a system element **1710** that is an 8-bit unsigned fixed-point number that indicates the system of units in effect for the enclosing units element **1702**. In some embodiments, the system element **1710** may be selected from one of those values specified in Table 30 below.

TABLE 30

Allowed values for the System tag in the Units structure.	
Value	Description
0	None
1	System International
2	English
3-255	Reserved

The units element **1702** may also include a description element **1712** is a caller-assigned, human-readable UTF-8 string that may be used to describe the specified units (e.g. "N" for kg*m/s^2). The units element **1702** may also include an exponent element **1714**. In the context of the units element **1702**, the exponent element **1714** is an 8-bit signed or unsigned fixed-point value that represents the exponent applied to the overall, composed Units. These correspond to common unit prefixes used to indicate a decadic multiple or fraction of the units. For example millimeters would have an exponent value of −3 and hectometers would have an exponent value of 2. When the exponent element **1714** is absent no prefix is applied to the units of measure. The units element **1702** includes a units sub-element **1716**. The units sub-element **1716**, in the context of a parent units element **1702**, is an array composed of one or more unit structures **1718**, as shown in FIG. **5** above. The unit structure **1718** is a structure, that when composed with all other unit structures **1718**, describes the derived quantity the data stream represents. Each unit structure **1718** may include a quantity element as a required 8-bit unsigned fixed-point value that represents the base unit in the system. In some embodiments, the quantity element **1720** may include a value selected from the values listed in Table 31 below.

TABLE 31

Example values for the Quantity tag in the Unit structure.				
Value	Quantity	None	SI	English
0	None	—	—	
1	Length	—	Meter	Inch
2	Mass	—	Kilogram	Slug
3	Time	—	Second	Second
4	Electric Current	—	Ampere	Ampere
5	Temperature	—	Celsius	Fahrenheit
6	Luminous Intensity	—	Candela	Candela
7	Amount	—	Mole	Mole
8	Plane Angle	—	Radians	Degrees
9	Solid Angle	—	Steradians	Square Degrees
10	Reserved	—		
. . .	. . .	—		
255	Reserved	—		

Each unit structure **1718** may also include an exponent element **1722**. The exponent element **1722**, in the context of the unit structure **1718**, is an 8-bit signed or unsigned fixed-point value that represents the exponent applied to the associated quantity element **1720**. In some embodiments, an omitted exponent element **1722** implies an exponent of 0 (e.g., $10^0=1$). For example 1/m^2 would have an exponent value of −2.

Returning to FIG. **42**, when the description element **1704** overrides any previously encountered in the parent descriptor structure **1654**. When the type element **1706** is present, the type element **1706** overrides any previously encountered in the parent descriptor structure **1654**. Similarly, in FIG. **41**, when the operation element **1676** is present it overrides any previously encountered in the parent descriptor structure **1692**.

The time period element **1672** of FIG. **43** is predicated on the assertion of the stream periodicity element **1660** and contains a single exponent element **1724**, as illustrated in FIG. **44**. The actual period value itself is contained within the stream element **1656**, described in detail below. The exponent element **1724** within the time period element **1672** is an 8-bit signed or unsigned fixed-point value indicating the base 10 exponent of the time period. For example, an exponent element **1724** value of −3 (10^{-3}) may indicate that the time period is specified in milliseconds.

The time base element **1670** of FIG. **40** within a descriptor structure **1654** includes a reference element **1726**, an exponent element **1728**, and a synchronization element **1730**. The reference element **1726** within the time base element **1670** is an 8-bit unsigned fixed-point value indicating the reference of the time base. In some embodiments, the time base element **1670** may be one of the non-reserved values specified in Table 32 below.

TABLE 32

Allowed values for the Time Base Reference element.		
Value	Mnemonic	Description
0	Monotonic	The monotonically increasing time from some implementation-dependent epoch.
1	Real Time	The current real-time time of day clock.
2-255	—	Reserved for future use.

For the monotonic reference, the epoch is system- and implementation-defined. The definition might, for example, be from a system power-on or boot-up time. For the real time reference, the Epoch is the POSIX or Unix Epoch of 1970-01-01T00:00:00Z, not counting leap seconds.

The exponent element **1728** within the time base element **1670** is an 8-bit signed or unsigned fixed-point value indicating the base 10 exponent of the time reference offset. For example, an Exponent value of −3 (10^{-3}) may indicate that the time base is specified in milliseconds from the Reference epoch. In some embodiments, an omitted Exponent element implies an exponent of 0 (10^0).

The synchronization element **1730** within the time base element **1670** is an 8-bit unsigned fixed-point value indicating the synchronization state of the time base. In some embodiments, the synchronization element **1730** may be one of the non-reserved values specified in Table 33 below.

TABLE 33

Allowed values for the Time Base Synchronization element.		
Value	Mnemonic	Description
0	Unknown	The state is indeterminate or unknown.
1	Synchronized	The state is synchronized.
2	Unsynchronized	The state is unsynchronized.
3-255	—	Reserved for future use.

FIG. **46** illustrates an example of a structure of the stream element **1656**. As previously discussed, each stream element **1656** includes a respective identifier field **1658**. Furthermore, each stream element **1656** includes a time base element **1732**, a time period element **1734**, and data element **1736**. In the context of a stream element **1656**, the time base element **1732** is a signed or unsigned, fixed-point element present when the time base element **1670** is also present in the corresponding descriptor element **1654**. The value represents the offset, in the magnitude specified by the exponent element **1728** of the time base element **1732**, **1671** from the reference element **1726** value.

Also, in the context of a stream element **1656**, the time period element **1734** is a signed or unsigned, fixed-point element present when the time period element **1672** is also present in the corresponding descriptor element **1654**. In this context, the time period element **1734** is the data for the metadata in the corresponding descriptor **1654**. The value represents the sampling period, in the magnitude specified by the exponent element **1728** of the time period element **1672** in the descriptor element **1654**, applicable to all the data samples.

The data element **1736** is a byte stream that represents the actual data samples described by the corresponding descriptor element **1654**. The data is interpreted with boundaries according to the Field Size and Count elements in the corresponding descriptor as shown in FIGS. **9** and **10** below.

ii. Example Data Arrangements

FIG. **47** depicts a flexible data arrangement with three (3), valid 5-bit fields and one (1), 1-bit padding field, achieving two-byte alignment. FIG. **48** depicts a flexible data arrangement with one (1), valid 7-bit field and one (1), 1-bit padding field, achieving one-byte alignment.

iii. Tags

Table 34 below summarizes a few possible tags used by this profile to format data. Each tag is subsequently described in detail.

TABLE 34

TLV tags defined for this profile.

Name	Tag Type	Element Type	Value
Streams	Fully-Qualified	Structure	0x01
Version	Context	U8	0x02
Descriptors	Context	Array	0x03
Descriptor	Context	Structure	0x04
Identifier	Context	U16	0x05
Type	Context	U16/U32	0x06
Derivation	Context	Structure	0x07
Operation	Context	U16/U32	0x08
Description	Context	UTF-8 String	0x09
Stream Periodicity	Context	Boolean	0x0A
Time Period	Context	Structure/[SU]	0x0B
Fields	Context	Array	0x0C
Field	Context	Structure	0x0D
Valid	Context	Boolean	0x0E
Relative	Context	Boolean	0x0F
Signed	Context	Boolean	0x10
Size	Context	U8	0x11
Count	Context	U8	0x12
Units	Context	Structure/Array	0x13
System	Context	U8	0x14
Unit	Context	Structure	0x15
Quantity	Context	U8	0x16
Exponent	Context	[SU]8	0x17
Logical Minimum	Context	Fixed	0x18
Logical Maximum	Context	Fixed	0x19
Physical Minimum	Context	Fixed	0x1A
Physical Maximum	Context	Fixed	0x1B
Records	Context	Array	0x1C
Stream	Context	Structure	0x1D

TABLE 34-continued

TLV tags defined for this profile.

Name	Tag Type	Element Type	Value
Data	Context	Data	0x1E
Time Base	Context	Structure/[SU]	0x1F
Reference	Context	U8	0x20
Synchronization	Context	U8	0x21
Operations	Context	Array	0x22

In some embodiments, in order to reduce RAM usage in RAM constrained devices, an effectively read-only descriptor portion of a stream may be composed at compile time and stored in read-only memory. Consequently, these implementations may use constants that can be specified and resolved at compile time and that are further amenable to macros suitable for packing and arranging the data in byte arrays.

When the sample rate of observed data changes, various methods for handling the changes may be employed. For example, the stream may be re-represented as an aperiodic stream. With the aperiodic option, the timestamps in the stream may change at any appropriate frequency with an added overhead of an absolute or relative timestamp for each data sample.

Additionally or alternatively, the stream may be submitted as n+1 different periodic streams, for n sampling rate changes. With this approach, the time period metadata and/or data will be different for each stream, corresponding to the sample rate change. These same options may be employed when there is a gap in the stream. In other words, the portions of the streams around the gap may be treated as different periodic streams.

FIG. **49** illustrates a flowchart view of an embodiment of a process **1800** for using the previously discussed time variant data profile. A smart device obtains data samples from one of its sensors (block **1802**). For example, the device may obtain temperature samples from a temperature sensor. In some embodiments, the data samples may be minimum or maximum values obtained by the sensor during a period of time. In other embodiments, the data samples may have a mathematical operation performed upon them by the smart device (block **1804**). For example, the data samples may be used in a transformative math operation to generate a mean, mode, median, or other operation for the data samples for a period of time within a whole period of time for the data samples. In some embodiments, the mathematical operation may include an identity operation that passes through values unchanged.

In certain embodiments, the smart device may also import some information from external resources in a first format. For example, the smart device may obtain data samples from memory of a remote device where the remote data samples are encoded in a specific format (e.g., TLV, JSON, XML, etc.) In some embodiments, the smart device may convert the remote data samples into a second format for use in a stream to be sent to other devices. In other embodiments, the remote data samples may simply be encoded in the first format in the stream. In further embodiments, the smart device may simply encode a location of a resource from which to import the data samples.

The smart device then encapsulates the data samples in a time variant data format previously discussed (block **1806**). For example, the data samples may be encoded in a stream structure within a general message that is tagged as using the time variant data profile. Furthermore, the stream structure may include a resource structure that provides identification of external resources encoded and/or to be encoded in the stream structure. The stream structure may also include the descriptor structure. As previously discussed, the descriptor structure includes an array of data that has been imported into the stream and/or the data samples from the sensor. Within the descriptor is a derivation structure that includes various metadata about the data therein. For example, as previously discussed, in some embodiments, encapsulating the data samples includes populating the derivation structure with information about a stride of the data samples, units for the data samples, exponent relating to scale (e.g., milliseconds or seconds) of the units, a time period of the data samples, indications of whether the data samples are measured in absolute time units or relative time units, and/or other information about the data samples. After the data samples have been encapsulated, the smart device may send to another device. (block **1808**). For example, the smart device may send the encapsulated data samples to other devices in the network, a device outside the network via a network gateway, and/or a remote service.

What is claimed is:

1. A non-transitory, computer-readable medium having stored thereon instructions for exchanging a data stream of information that varies over time using a message format, wherein the message format comprises:

a version field that indicates a version of a structure of the message format;

one or more resources fields that each identifies a resource to be imported into the data stream exchanging the data stream;

one or more records that represent time-variant data samples being exchanged in the message;

one or more descriptor fields, wherein each descriptor field corresponds to at least one respective record of the one or more records and contains metadata describing data contained within the at least one record; and

a description field having a human-readable string formatted in Universal Character Set and Transformation Format (UTF) to describe a time-variant stream from which the time-variant data samples are derived, wherein the description field is configured to enable later analysis of the exchange of the data stream.

2. The non-transitory, computer-readable medium of claim **1**, wherein the UTF comprises Universal Character Set and Transformation Format-8 bit (UTF-8).

3. The non-transitory, computer-readable medium of claim **1**, wherein each of the one or more resource fields comprises a string comprising a Uniform Resource Identifier (URI) that maps to a resource to be imported into the message, wherein each URI is a string that identifies a location of the resource to be imported.

4. The non-transitory, computer-readable medium of claim **3**, wherein the URI refers to a resource that is common between vendors or are public descriptors, and the URI comprises a Uniform Resource Locator (URL) that sets a Multi-Purpose Internet Extensions (MIME) type that is an indicator of encoding of the resource to be fetched for importing into the data stream.

5. The non-transitory, computer-readable medium of claim **3**, wherein each of the one or more resource fields comprise a source indication that identifies a specific location within the resource from which imported data is to be derived, wherein the source indication comprises:

an explicit indication that explicitly states where the imported data is specifically located within the resource; or

an implicit indication when an explicit indication is lacking, wherein the implicit indication indicates that the specific location of the imported data is in a root location of the resource.

6. The non-transitory, computer-readable medium of claim **3**, wherein the instructions are configured to cause a processor to import multiple resources into a single destination by concatenating data from the multiple resources into a destination indicated by the destination field, wherein an order of the concatenated data corresponds to an order of the multiple resources in the message.

7. An electronic device comprising:

a processor; and

a memory comprising instructions for causing the processor to exchange a data stream of information that varies over time using a message format, wherein the message format comprises:

a version field that indicates a version of a structure of the message format;

one or more resources fields that each identifies a resource to be imported into the data stream exchanging the data stream;

one or more records that represent time-variant data samples being exchanged in the message; and

one or more descriptor fields, wherein each descriptor field corresponds to at least one respective record of the one or more records and contains metadata describing data contained within the at least one record; and

a description field having a human-readable string formatted in Universal Character Set and Transformation Format (UTF) to describe a time-variant stream from which the time-variant data samples are derived, wherein the description field is configured to enable later analysis of the exchange of the data stream.

8. The electronic device of claim **7**, wherein the descriptor field comprises a 16-bit unsigned fixed-point value identifier that matches a corresponding identifier in a corresponding record to indicate that the descriptor field describes data found in the record is described by the metadata in the descriptor field.

9. The electronic device of claim **7**, wherein the resource indicated in a location external to the electronic device, the data in the external resource is formatted in tag-length-value (TLV) format, a profile tag for the descriptor field may be context-specific by using a top level profile tag to indicate the descriptor field refers to an exterior resource by tagging the descriptor field with a 0x02 value in an ExtDescriptors tag.

10. The electronic device of claim **7**, wherein descriptor field includes a stream periodicity indicator that indicates whether data in the stream is periodic or aperiodic using a flag, wherein when the flag is positive, indicates that the stream is periodic, and when the flag is negative, indicates that the stream is aperiodic having irregular intervals of time between samples in the stream.

11. The electronic device of claim **7**, wherein the descriptor field comprises a type element that is a caller-assigned 16-bit or 32-bit unsigned fixed-point value that represents a type of data present in the stream, wherein the type element applies to field elements found in the descriptor field unless explicitly overridden by another type element contained in a respective field element of the descriptor.

12. The electronic device of claim 11, wherein the type comprises length, mass, time, current, temperature, luminous intensity, area, volume, velocity, acceleration, density, magnetic field strength, luminance, molar concentration, number concentration, molality, frequency, force, pressure, energy, power, electric charge, capacitance, electrical resistance, magnetic flux, electrical resistance, radioactivity, depth, height, or humidity.

13. The electronic device of claim 11, wherein the type element comprises:

a first portion of the type element that indicates a vendor identifier for a vendor of the resource containing data to be imported; and

a second portion of the type element that indicates a type of data specific to data points derived from a device having a specific vendor identifier.

14. A method for conveying time-variant data, comprising:

transmitting, using a network interface, data to exchange a data stream of information that varies over time using a message format, wherein the message format comprises:

a version field that indicates a version of a structure of the message format;

one or more resources fields that each identifies a resource to be imported into the data stream exchanging the data stream;

one or more records that represent time-variant data samples being exchanged in the message;

one or more descriptor fields, wherein each descriptor field corresponds to at least one respective record of the one or more records and contains metadata describing data contained within the at least one record; and

a description field having a human-readable string formatted in Universal Character Set and Transformation Format (UTF) to describe a time-variant stream from which the time-variant data samples are derived, wherein the description field is configured to enable later analysis of the exchange of the data stream.

15. The method of claim 14, wherein the descriptor element comprises a field element that describes the format of one or more data samples found in the message, wherein the field element comprises:

a valid element that is a Boolean flag used to indicate whether the field contains alignment padding or valid data;

a relative element that is a conditional Boolean flag that is used to indicate whether the samples are measured absolutely or relative to each other;

a signed element that indicates whether the data samples are signed or unsigned values;

one or more size elements that are each an 8-bit unsigned fixed-point value that indicates a size of corresponding data sample; and

a count element is an 8-bit unsigned fixed-point value that indicates a number of size elements for the field element.

16. The method of claim 15, wherein the field element comprises:

an exponent element that is an 8-bit value used to indicate an exponent of the data to preserve resolution while scaling the data samples; and

a units element that includes metadata describing units of measure represented by the data samples;

one or more overriding elements configured to override, for the field element, metadata referring to the one or more records, wherein the one or more overriding elements comprise a data type or a description for the data samples.

17. The method of claim 15, wherein the units element comprises:

a system element that is an 8-bit unsigned fixed-point number that indicates a system of units in effect for the units element; and

a description element that is a caller-assigned, human-readable Uniform Character Set and Transform Format 8 bit (UTF-8) string that may be used to describe the specified units.

18. The method of claim 15, wherein the field element comprises:

a logical minimum field that indicates a minimum expected, valid logical value for a corresponding data sample based on the signed and size elements; and

a logical maximum field that indicates a minimum expected, valid logical value for a corresponding data sample based on the signed and size elements.

19. The method of claim 14, wherein the descriptor element comprises a time base element that indicates time base information about the stream comprising:

a reference element that is an 8-bit unsigned fixed-point value indicating whether the clock is real time or incremental;

an exponent element that is an 8-bit fixed-point value indicating a base ten exponent of units of time used to track the data samples;

a synchronization element that is an 8-bit unsigned fixed-point value indicating whether the time base is synchronized, unsynchronized, or unknown.

20. The method of claim 14, wherein the descriptor element comprises a time period element that indicates intervals between data samples of the data stream of when the data stream is indicated as periodic, wherein the time period element comprises an exponent element that is an 8-bit fixed-point value indicating a base ten exponent of the interval in relation to seconds as a base unit.

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